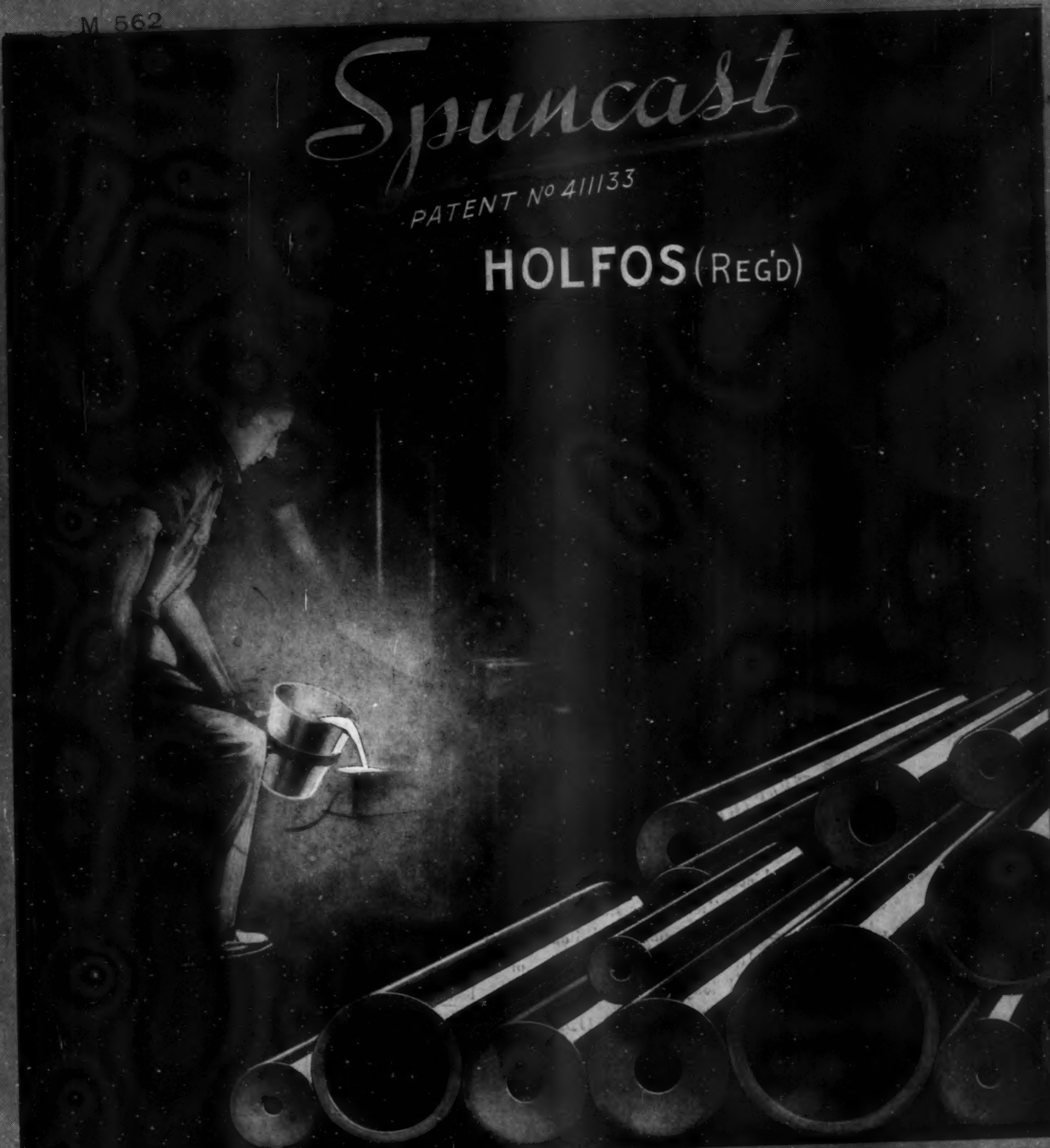
Vol. 17. No. 101. MARCH, 1938. Price 2/-. [Subscription 25/- per annum, post free.]

METALLURGIA

THE BRITISH JOURNAL OF METALS

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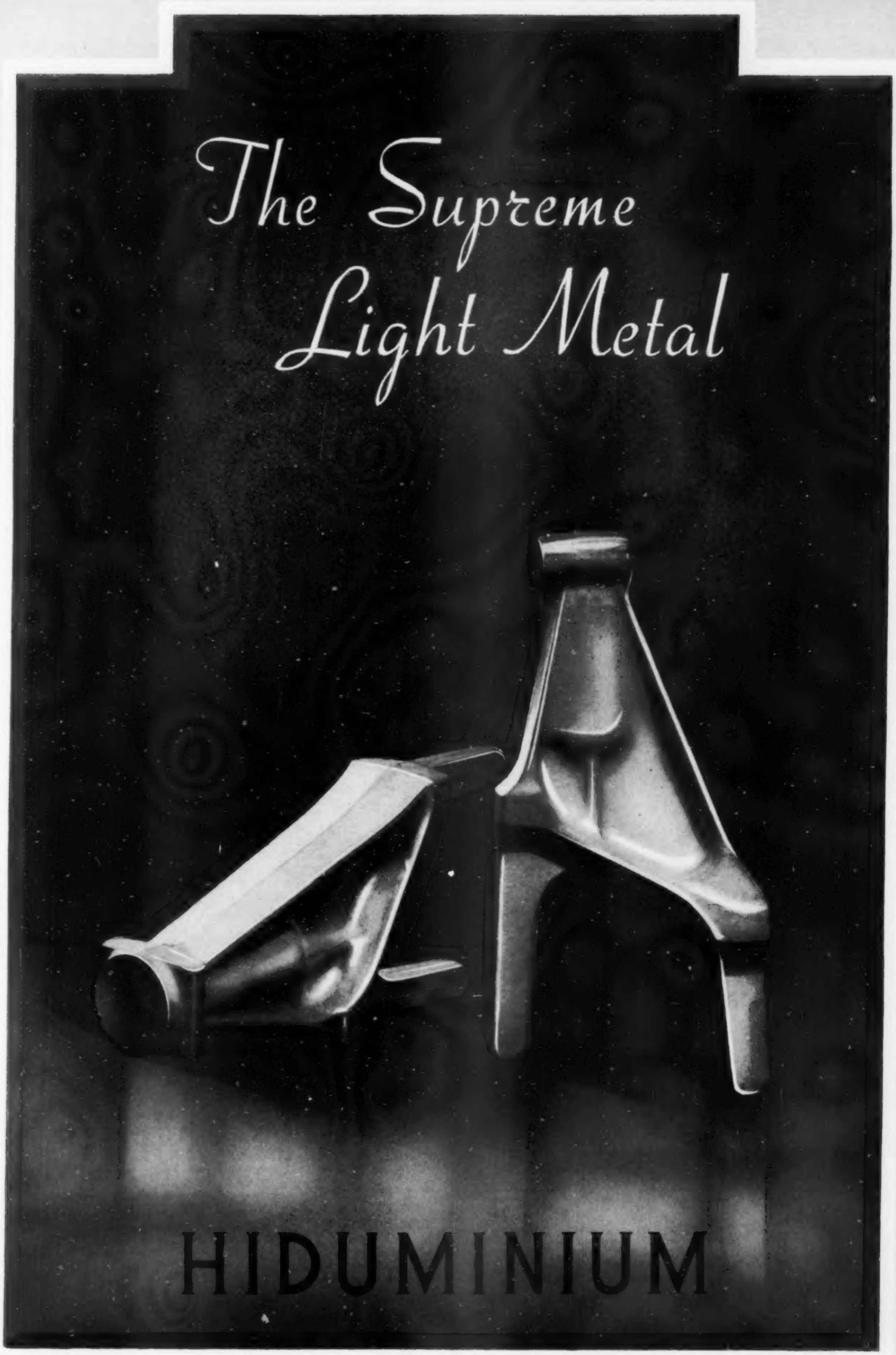

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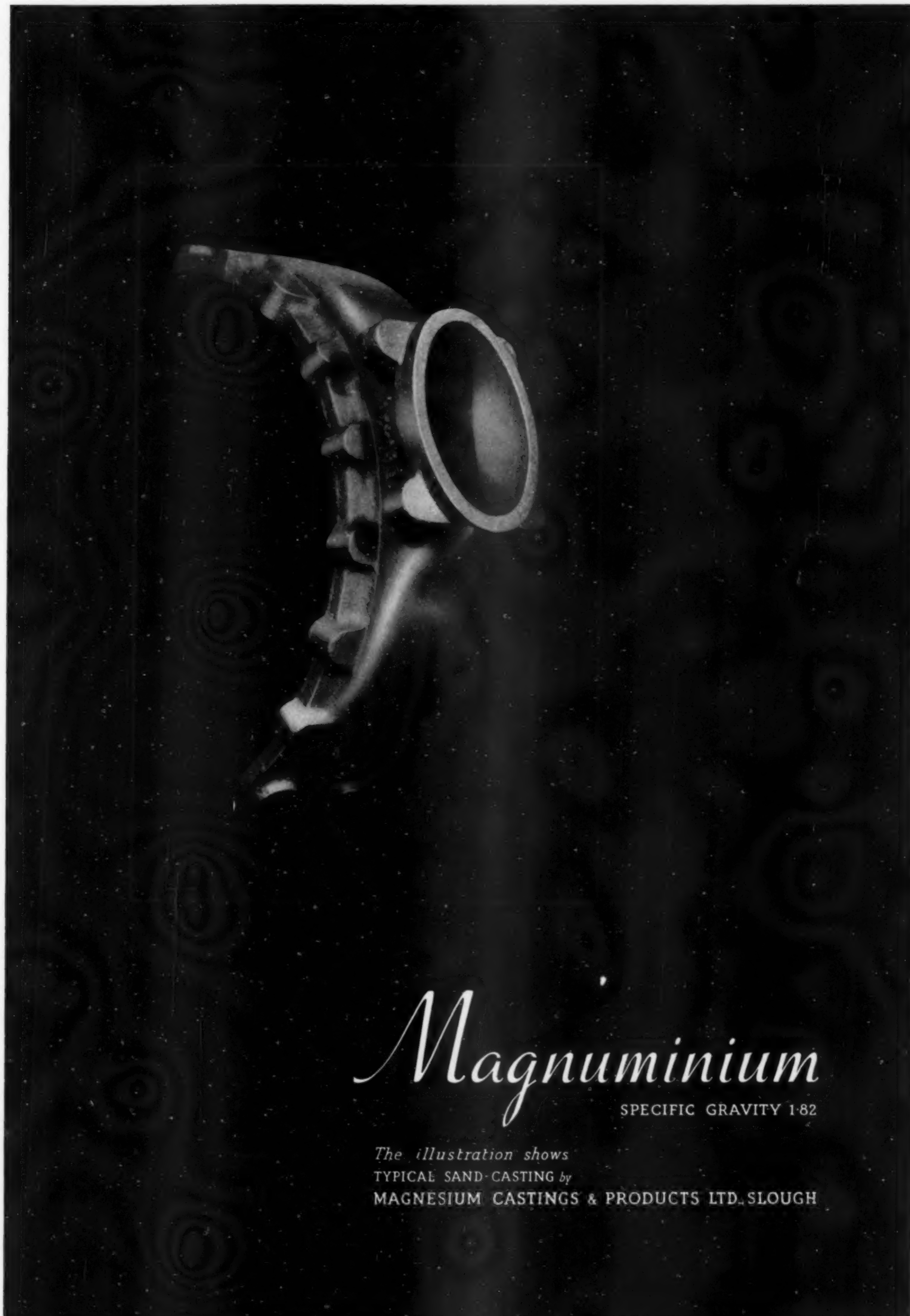
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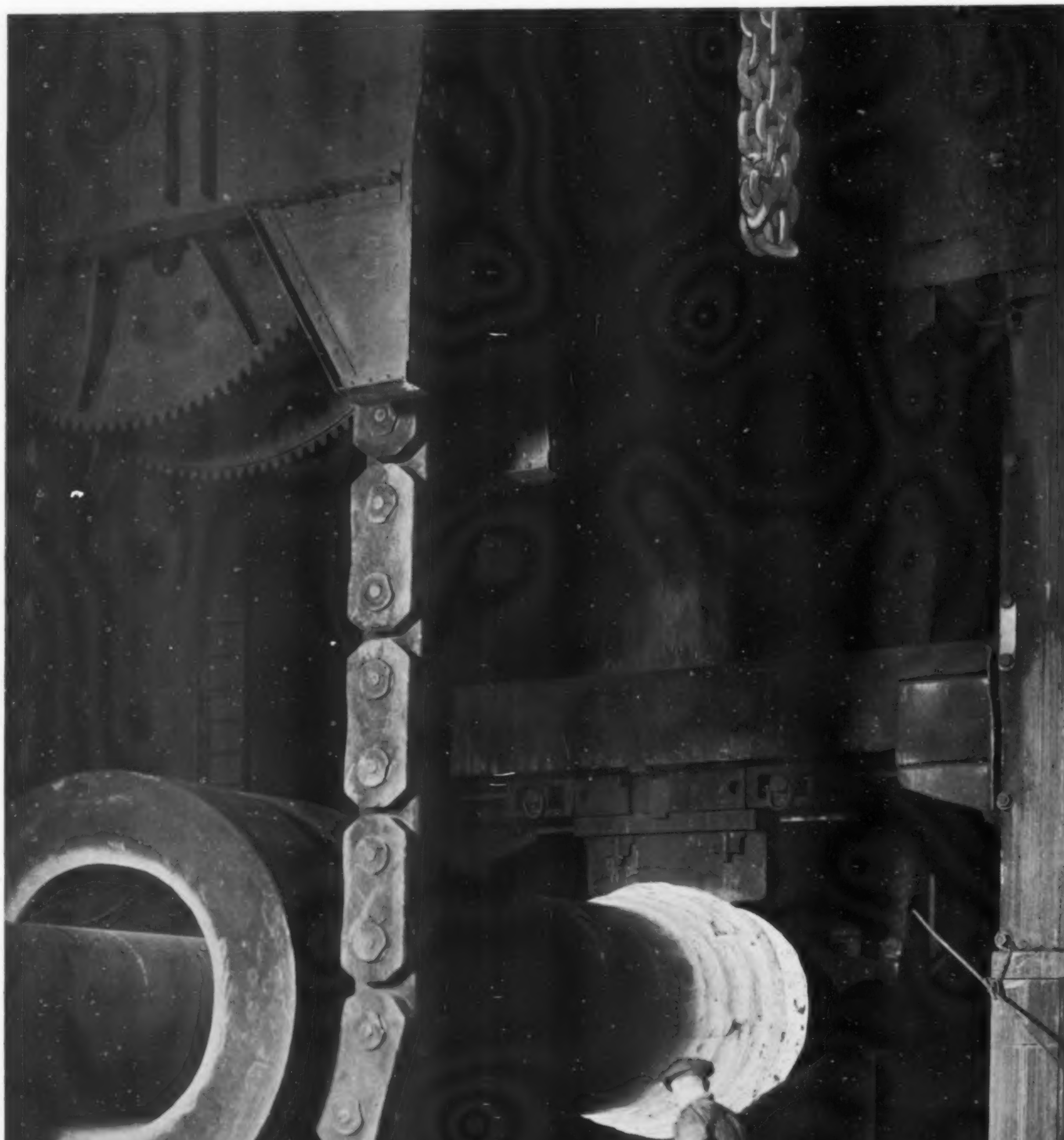
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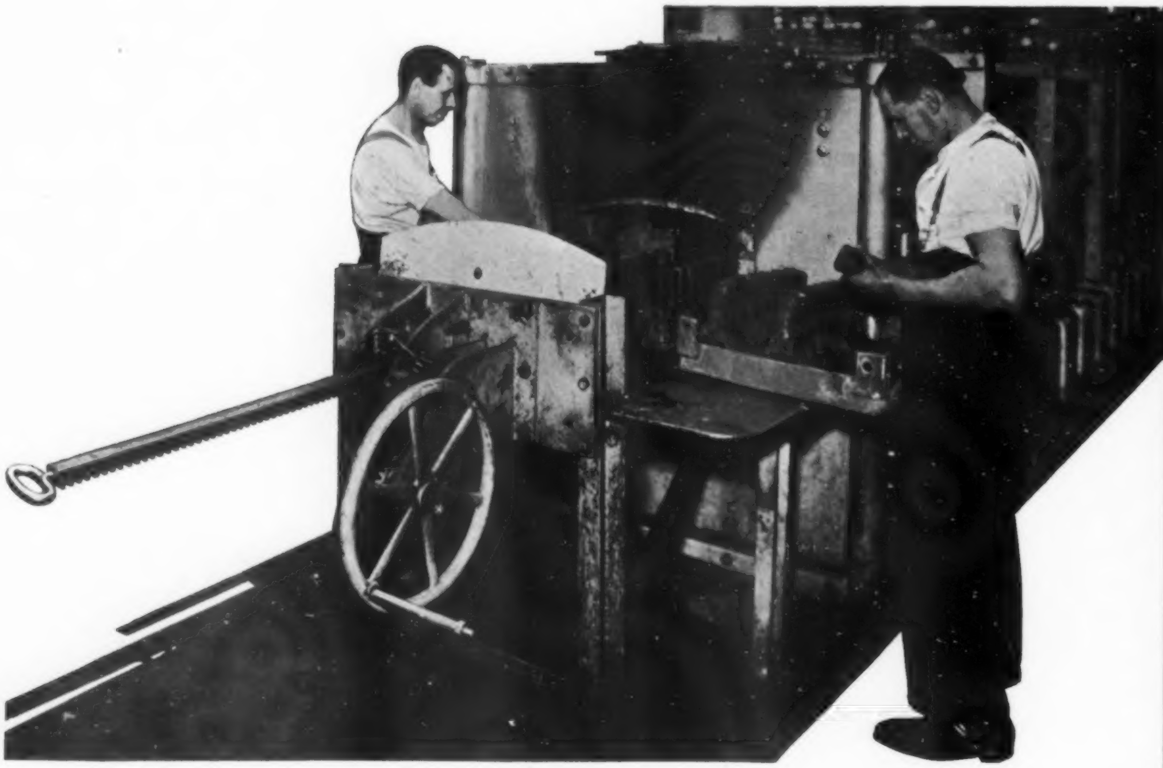

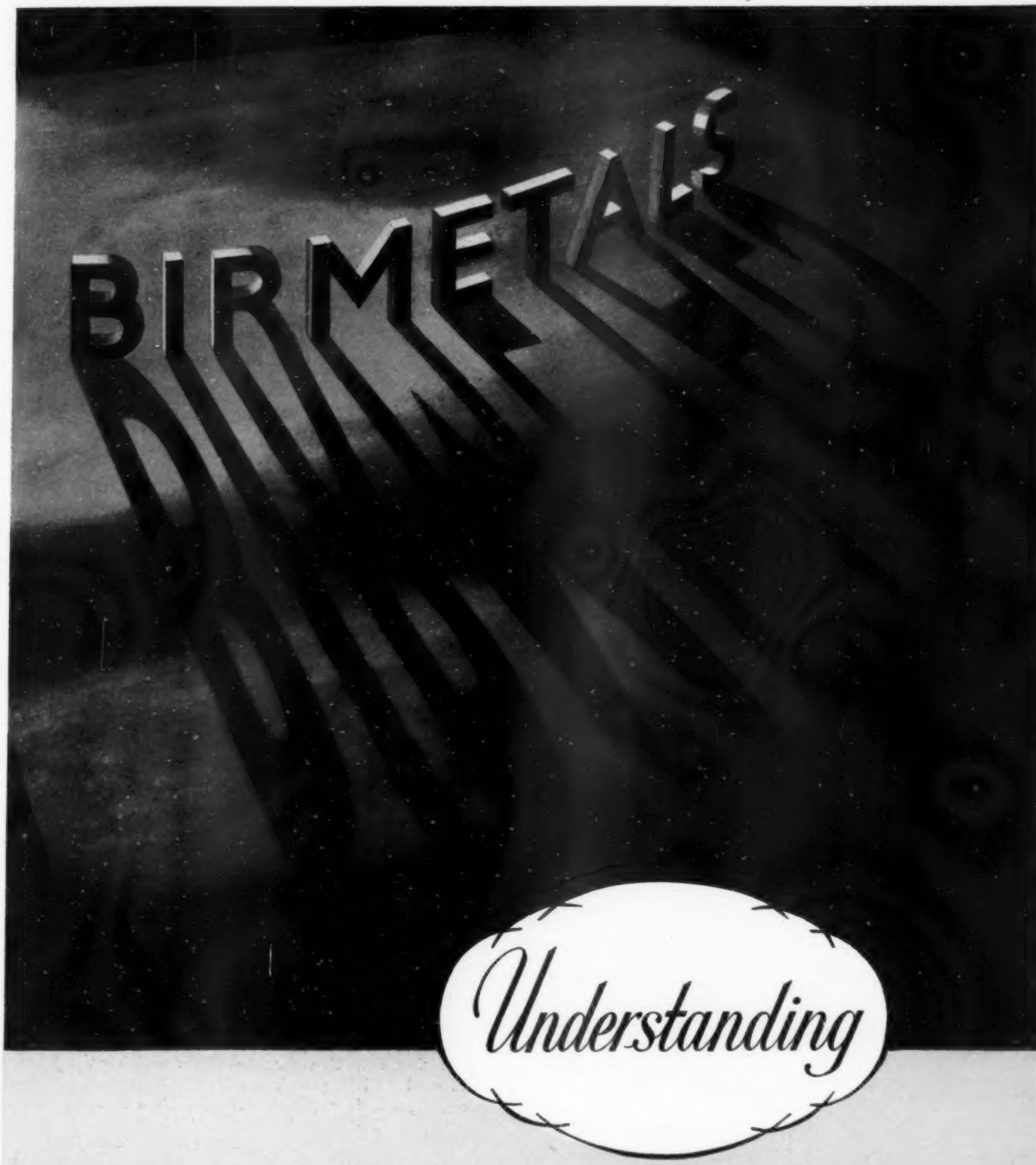
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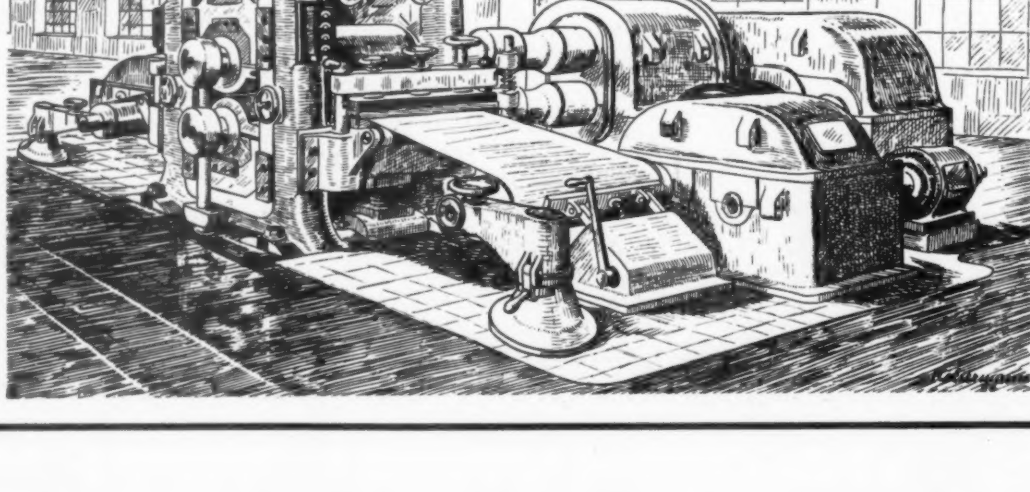

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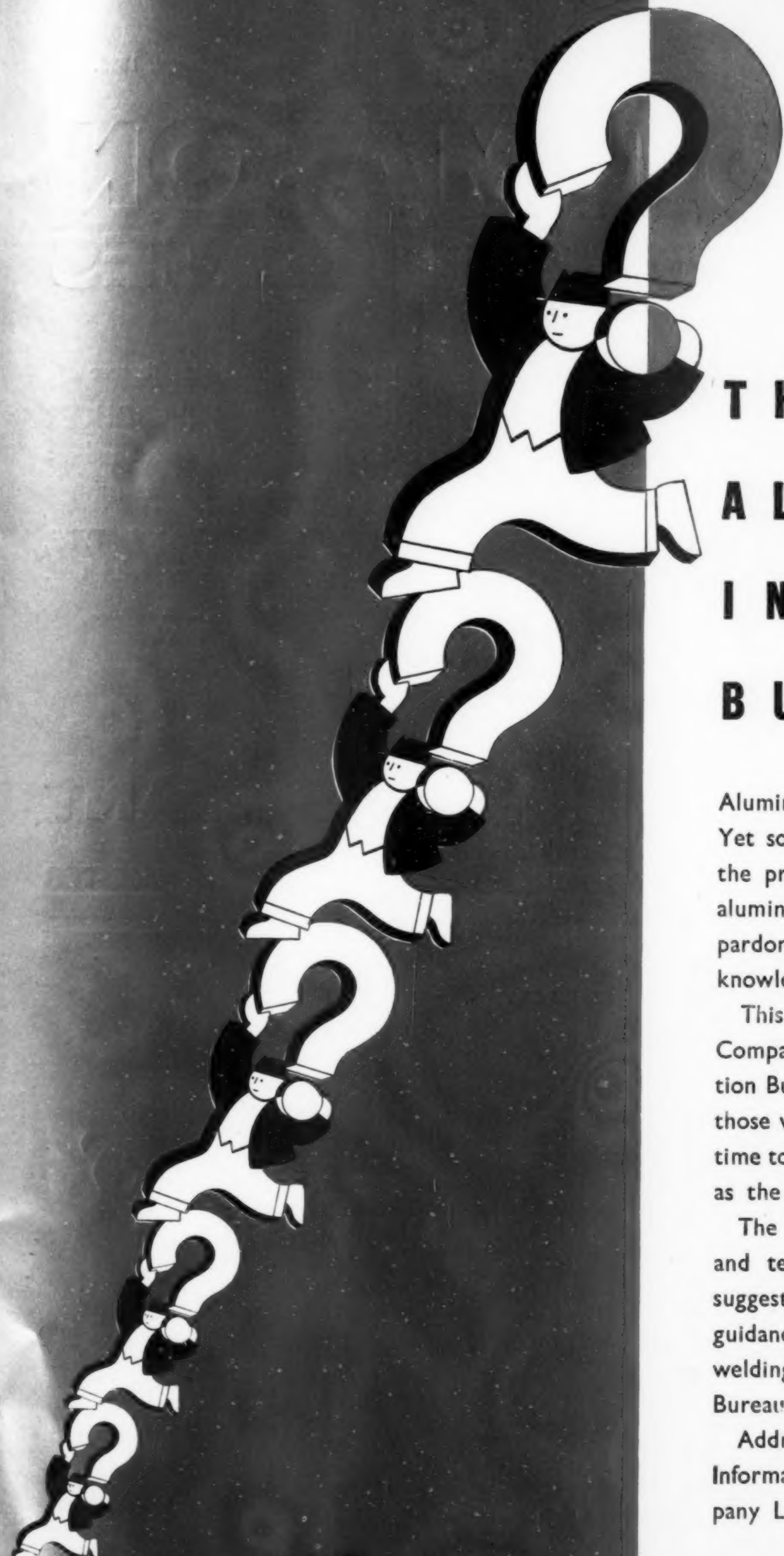

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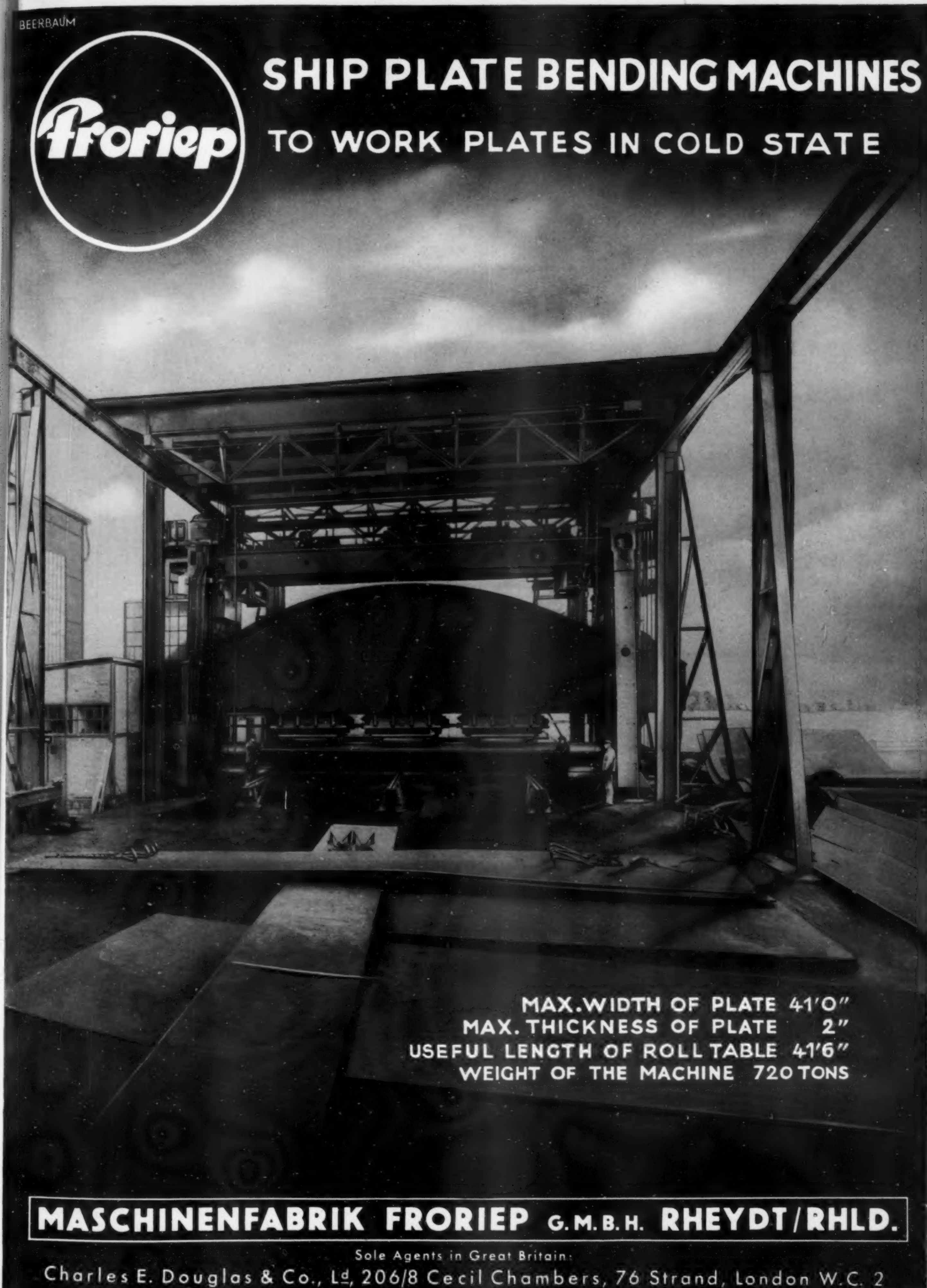
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The British Journal of Metals

(INCORPORATING THE METALLURGICAL ENGINEER.)

Contributions suitable for the editorial pages are invited. Photographs and drawings suitable for reproduction are welcome. Contributions are paid for at the usual rates.

PRINCIPAL CONTENTS IN THIS ISSUE:

Subscription Rates throughout the World - - 24/- per annum, Post free.

Published Monthly by the Proprietors, THE KENNEDY PRESS LIMITED, at 21, Albion Street, Gaythorn, Manchester.

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METALLURGIA

THE BRITISH JOURNAL OF METALS.
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MARCH, 1938. VOL. XVII. No. 101.

Market Forms of Aluminium and Its Alloys

By WILLIAM ASHCROFT

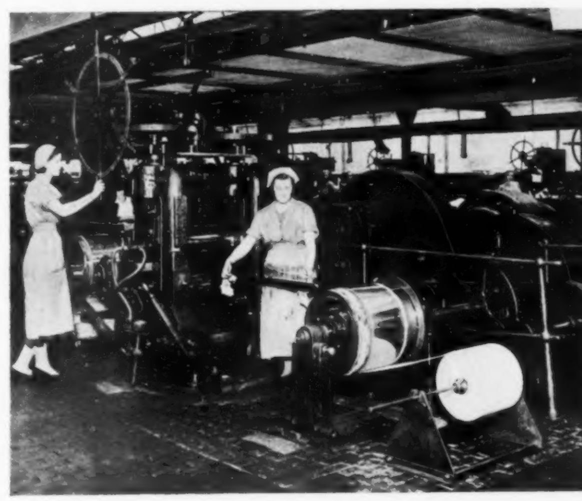
Recent years have seen great progress in the use of aluminium and its alloys which has led to the marketing of these materials in forms that meet a demand and in this article the various market forms and conditions of aluminium are reviewed.

THE forms in which aluminium and its alloys are available may be broadly divided into two main groups: wrought and cast forms. Each group includes a very wide range of compositions, some of which can be given a suitable heat-treatment to improve their mechanical properties, and by varying the heat-treatment it is possible to produce from the same alloy a number of different combinations of mechanical properties. The alloys for sand- and die-casting, which are available in bar and ingot form, include alloys in which silicon, copper, magnesium, zinc or manganese is the main alloying element. Each is produced in a range of compositions in which the content of the main alloying constituent varies and in which small percentages of other alloying elements may be present.

Wrought products are available in the form of sheet, plate, circles, rod, wire and bar, as extruded sections and tubing. For convenience they are divided into two main classes: common alloys, and strong alloys. The former includes commercially pure aluminium, and the alloys, aluminium-manganese, aluminium-manganese-magnesium, and aluminium-silicon, which do not respond to heat-treatment, but are subject to strain-hardening. The strong alloys comprise the aluminium-copper-magnesium-manganese alloys, aluminium-silicon alloys with a higher silicon content than those included in the common alloys, aluminium-silicon-magnesium alloys and aluminium-magnesium-silicon alloys. In these alloys also, small percentages of other elements are usually present.

Commercial aluminium in practically all semi-finished forms ordinarily contains 99% minimum aluminium, but under some specifications 98% minimum aluminium is acceptable, generally, however, 99% minimum is now demanded. Ordinary 99+% aluminium in these commercial forms may contain up to 0·15% copper, 0·35% silicon, and 0·45% iron, while minor percentages of manganese, zinc and other impurities may be present. As a rule, the 99+% material is generally satisfactory, providing the impurities are normal. The 98 to 99% material meets requirements for many purposes where a hard or intermediate temper can be used, as in sheet when it is not subjected to severe deformation in working, or is not exposed in service to harmful corrosive influences. For deep drawing, spinning, stamping and other forming operations, the grade containing 99% or over is normally necessary. The resistance to corrosion of this grade is generally superior to that of the less pure grades, but for many purposes the trend is towards products of greater purity, particularly for making aluminium foil, collapsible tubes and for certain types of chemical and clinical apparatus.

As has already been pointed out, a number of alloys are produced in semi-finished forms to be used for many purposes that call for a stronger and stiffer material than aluminium, but where the special properties of the heat-treatable alloys are not required. Such alloys are subject only to strain hardening and do not respond to heat-treatment.



Rolling aluminium strip at the Warrington works of the British Aluminium Co. Ltd.

The greater proportion of semi-finished aluminium and aluminium alloy products are in the form of sheet and extruded sections. Sheet is supplied in various grades, sizes, gauges, tempers and surface finishes to meet the diverse requirements of consumers in the stamping, fabricating and speciality manufacturing trades. Flat sheet may be obtained in two kinds of surface finishes—a bright finish or a grey finish. The latter usually applies to sheet of rather heavier gauge. Flat sheet is usually planished during the time of rolling, highly polished rolls being used. As a rule aluminium has a higher polish imparted to it during rolling than an alloy, but in each case the quality of the polish may be increased by means of several finishing passes when rolling. In addition to the finishes mentioned, aluminium and aluminium alloy sheet may have special surface finishes, such as satin finish or scratch-brush, and matte or dip finish.

Of more importance, especially from a working point of view, is the range of tempers in which sheet is supplied. Consumers should be familiar with the grade and temper of the aluminium and alloy sheet suitable for the particular application and with the work to be done in making the final product. Sheet is available in a wide range of tempers

or heat-treatments. The tempers of the common alloys, for instance, depend upon the amount of cold working or strain hardening given the metal during fabrication and range from the soft annealed condition to the full, hard condition. There are several intermediate tempers between these two extremes which are usually designated quarter-hard, half-hard, and three-quarter-hard. It should, of course, be remembered that the strength of these alloys increases with increased cold work, but the elongation and workability are decreased. This range of tempers gives a corresponding range of mechanical properties which meets general requirements.

The heat-treatable alloys are generally available, in the various semi-finished forms, in the annealed condition, quenched or solution, or in the fully heat-treated condition. The full heat-treatment comprises both solution and precipitation heat-treatments. The solution heat-treatment consists in raising the metal to a high temperature and then quenching, generally in cold water. In the quenched condition the alloys have reasonable ductility and can be readily worked. Certain alloys, those of the Duralumin type, for instance, if left in this condition at room temperature, will age-harden or undergo the precipitation heat-treatment spontaneously, attaining their maximum properties after four or five days. Other alloys, on the other hand, have a stable quenched condition in which reasonable forming operations can be carried out at any time. Subsequent heating at a temperature ranging from 120° to 160° C. is required to give these alloys their maximum mechanical properties.

Too much space would be required here to describe the manifold uses of the various semi-finished aluminium and aluminium alloy products available, readers are referred to the various applications given elsewhere in this issue, but some reference may profitably be made to costs. The prices charged for the different kinds and grades of these semi-finished products necessarily vary, depending upon the grade, quantity and size. Considerable saving can frequently be effected if consumers communicate with producers regarding the uses to which the particular product is to be put; in this way the producer, through his technical department, may not only suggest a less expensive grade, but reduce forming difficulties which might otherwise arise.

Artificial Resin Bearings in Rolling Mills

Favourable results have been obtained from the use of these bearings; here economic results are discussed.

IN a recent issue[1] we reported on a paper by Carl Fläschel[2] before the Rolling Committee of the "Verein deutscher Eisenhüttenleute," on roller bearings. At the same meeting a report was given by Schiffers[3] dealing with experience on bearings of artificial resin which may be of interest to readers. Investigations were also carried out at the iron and steel works of Neunkirchen (Saar) on wire rod, strip and bar mills.

The first step towards the introduction of bearings of artificial resin was a standardisation of the types of bearings used at the time, so as to economise in the expense of forming discs as much as possible. It was possible to reduce the 28 types of bearings to 12, a result which was the more remarkable as the 28 types had already been the consequence of a former standardisation.

Owing to lack of space, we must again omit the interesting discussion on the reasons governing the choice of design and of the quality of the various bearings, also of constructive details such as dimensions of the roll neck, layout of the cooling system, and cleaning of the cooling water, etc. Similarly, the general remarks contained in our review of the Fläschel report hold good also in this case. Here the economic results only are reported.

The following points are considered:

1. *First costs.*—These are about twice as heavy as in the case of bearings of brass, and about three times those of lignum vitae.

2. *Durability.*—Artificial resin is about six times as durable as lignum vitae and about fifteen times as durable as brass.

Combining 1 and 2 we obtain the following results in comparison with artificial resin:

(*a*) At the wire-rod mill, lignum vitae 1½ times more expensive; brass, 7½ times more expensive.
(*b*) At the strip mill, brass 12 times more expensive.
(*c*) At the bar mill, lignum vitae 1¾ times more expensive; brass 7 times more expensive.

3. *Electric Current.*—Saving is very important—between 9·5 and 16%. This resulted in an increase of production of 5%, which would otherwise have been impossible with the comparatively weak motors.

4. *Stoppages.*—None took place due to bearings having to be changed during production time. So that about six additional hours' working-time per year and per mill could be obtained, or 36 hours per year for the six mills which have been equipped with bearings of artificial resin.

5 and 6. *Savings on the rolls and lubricants* are themselves other savings.

The total savings are summarised as follows:

1. By increased durability: 3·1 pfennig per ton production.
2. By decreased electric current consumption: 27·3 pfennig per ton production.
3. By increased production: 37·0 pfennig per ton production.
4. By cutting out stoppages due to change of bearings during production time: 1·7 pfennig per ton production.
5. By longer life of rolls: 3·4 pfennig per ton production.
6. By use of less lubricants: 0·5 pfennig per ton production.

Thus making a total saving of 73·0 pfennig per ton production.

As these figures are valid for a total production of 310,000 tons per year, they represent a total saving of about 226,000 marks per year. (Of course, this result holds only under the working conditions of the Neunkirchen Iron and Steel Works; we have, therefore, omitted to convert the German money into English—moreover, there is difficulty in comparison due to fluctuation in the rate of exchange.)

In considering these figures one must further take into account that no provision is made for the smaller rolling tolerances which can be obtained with bearings of artificial resin. It was observed for instance, that the difference between the top and the bottom end of a length of wire, 60 to 100 metres long, was reduced from 0·2 mm. when using brass or lignum vitae bearings to 0·1 mm. with artificial resin bearings.

The use of such bearings in a roughing mill was also reported, and favourable results were also obtained; the figures, however, are of minor interest, as the investigations had to be interrupted after a comparatively short time.

1 METALLURGIA. Vol. 16, No. 94, p. 118.
2 Report of Carl Fläschel. *Stahl und Eisen*, vol. 37, No. 24, 1937.
3 Report No. 136. *Stahl und Eisen*. Vol. 37, No. 18, 1937.

Water-Cooled Non-Ferrous Moulds

By Dr. KARL SCHERZER

The non-ferrous billet caster is able to produce billets possessing a more perfect surface with greater freedom from porosity than formerly, progress in this direction is due, in some measure, to the adoption of moulds of the water-cooled type. In a recent lecture, before the Midland Metallurgical Societies, the author discussed the subject in the light of modern practice, an abstract of which is given in this article.

THE water-cooled mould was first brought into continuous service by Herr Andreas Junker, in 1912-13, in the Stollburger Metallwerke, Stolberg, Germany. The idea was first mentioned in patents in 1880, but a considerable amount of experimental work was necessary, and prejudices overcome before the water-cooled mould was accepted. The first water-cooled moulds for casting brass slabs of about 1 in. by 10 in. by 44 in. were lined with mild-steel plates, and were a marked advantage over the solid cast-iron moulds, because the cooled steel plates gave a smooth surface. But the steel plates were subject to warping, owing to temperature stress, and could not resist for long the tendency to form cracks. This was the reason for changing the lining material to soft copper which is, owing to its softness, not so subject to warping or breaking. The better conductivity of heat through the copper plate and the neutrality of the copper against dressing containing carbon were further advantages.

Each part of these moulds consists of an iron or steel water jacket with water distributing and collecting pipes, covered on the casting side by the copper plate of normally-rolled soft copper about ½-in. thick, fixed by bolts and a packing to the water chamber. The water-cooled mould should not be connected to a closed system of circulating water, at least, not slab moulds. Imagine a normal mould with dimensions of about 775 sq. in. and a water pressure of one atü, there would be a total pressure of five tons on the copper plate, tending to deform it towards the inside. The water chamber is therefore subdivided by backing ribs, which prevent the copper plates from bulging towards the cooling chamber. The water piping is arranged in a manner which keeps the mould full, and no back pressure of the water is allowed on the outlet.

For casting round billets the use of water-cooled moulds began later than for slabs, the reason probably being that there was less need for a smooth surface for extrusion; but in a few years the water-cooled non-split common billet has been accepted in most of the European metal works. The construction is similar to that of the slab mould, except that the lining consists of a copper tube of ½ in. to 1 in. wall thickness, and in some cases of cast-iron tubes of 1 in. to 2 in. wall thickness. Contrary to the slab mould, the inner lining of the billet mould is fixed only at one end, and the other end is provided with a packing, permitting the hot tube to expand or contract.

In spite of the fact that the water-cooled mould is not a remedy for all foundry troubles, there are outstanding advantages which have led to its general adoption in all the bigger European brass mills and in extrusion works. These advantages may be found in the following points: The water-cooled mould gives a good and constant surface to the ingot, comparable to that of a new mould. The trouble arising from rough surfaces was the main reason for improving the old cast-iron mould. The copper lining of the water-cooled mould, which is not affected either by heat or by the dressing and which is equally smooth whether on the first or five thousandth casting, has solved this problem fundamentally. The water-cooled mould is practically without wear, cracks, however, may develop in the copper linings of slab moulds after some 5,000 castings, but repairs can be effected. For copper tubes in round moulds a life of 15,000 castings and more is nothing unusual, providing that the tube is not mechanically damaged.

The handling is much easier and simpler, as the mould is equipped with hinges, better closing devices, pouring bowls on rails, etc., which make the handling easier. One man can manage the mould or moulds for two furnaces, each of 600 kg. capacity. Supposing an average of six to eight castings per furnace in eight hours, this gives a production of seven to 10 tons per eight hours' shift of one mould operator. The time of casting is reduced, and it is possible to empty the mould in two to four minutes after pouring. Five minutes later the same mould can be ready for another casting, and it is possible to use one water-cooled mould for three or four furnaces, mounted, for preference, on a truck running on rails in front of the casting platform. This means that the number of moulds which must be kept in stock is considerably reduced, possibly to one mould if the foundry can accept one standard size. For slab moulds the width of the ingot can be made variable within certain limits.

With regard to the extra cost of cooling water, it will be recognised that the water can be recuperated after passing through the mould. In many foundries, the water supply for the moulds is arranged as follows: One tank of a capacity sufficient to supply water for all furnaces casting at once is arranged at a height which gives a pressure of ½ to 1½ atü—that is 20 ft. to 60 ft. above the level of the mould. Another basin three to four times the capacity of the pressure tank is arranged underground. The way between mould and basin and the basin itself is open to allow the water to cool down. The upper tank is filled from the lower basin by a 3-h.p. pump supplying sufficient for two to two and a-half tons of metal per hour.

The water-cooled mould was originally developed for the brass foundry, or more precisely the foundry associated with brass rolling mills. Here the water-cooled mould is accepted where heavier slabs are cast, and in Germany it can safely be said that all brass plate comes from a water-cooled mould. In other European countries and over-seas the water-cooled mould has found its way into most of the larger brass foundries for hot-rolling operations. It has, however, not been equally well received in British foundries which make a variety of smaller ingots, nor in American brass foundries, where the long and narrow ingot of only about 50 kg. weight still predominates.

It must be admitted that in the small English brass foundries a very good quality of ingot is produced in sold moulds, and therefore the need to change this method may not be felt so long as it is not required to increase or standardise the size of the slabs. It may also be that the British market has a certain aversion to standardised size of ingots, which the water-cooled mould would certainly bring; still, it does not appear clear why this type of mould has not made better progress in this country, since the Stolberg Metalworks, when first installing the water-cooled mould, worked on rather similar lines and with variable dimensions for not less than eight to 10 years with water-cooled moulds with convincing success, before they changed in 1920-21 to hot rolling and heavy slabs,

The safety of water-cooled moulds is high, as high as anything can be in a place where people deal with liquid metal. In the run of 25 years a few accidents have happened, but only in cases of very extraordinary treatment of the mould.

The same moulds as for brass are used with success for deoxidised copper, if cast in smaller quantities. The casting temperature is higher, therefore the amount of cooling water is greater, and only a very thin dressing may be supplied. For the larger quantities of refined copper the United States Metals Refining Works have developed a system of water-cooled moulds since about 1929.

It is strange that the water-cooled mould makes little progress in the iron and steel foundry. In an iron foundry a normal billet mould of about 120 mm. diameter, and 1,000 mm. in length is used for casting bars which are cut or machined into discs, and other parts for simple bearings. The casting in the water-cooled mould gives a fine Perlit-like structure to the iron. In foundries where ordinary steel is cast, probably the large number of moulds, the variety of dimensions and the fear of dealing with water in the casting pit near the liquid steel have, until now, prevented the use of water-cooled moulds.

Prospecting for Gold in South Urals

THE geological trust Myass-Zoloto last year for the first time made wide use of geophysical methods in prospecting for quartz veins. The good results obtained in three different regions from experiments with these methods have induced the trust to apply them on an industrial scale in 1938. Last year, too, composite prospecting was organised for the first time. In two different regions, in addition to gold, the prospectors found zirconium and ilmenite of industrial importance. The production of zirconium has already been commenced and several tons of the metal have been sent to the trust Dragolovo. Not far from Chelyabinsk, in a district which had hitherto not been prospected for gold, was found a suite of quartz veins of high gold content. Geological prospecting work on an industrial scale will be carried out in this region in 1938. The newly-found deposit opens up big prospects for the development of a gold industry in the South Urals.

Use of Waste from Alumina Production

LARGE quantities of waste products result from the production of alumina and during recent years attention has been directed to the profitable utilisation of these waste materials. The red sludge obtained from the European bauxite by the Bayer process is probably the most useful because of its comparatively high content of iron oxide. This red sludge, after drying contains up to 35% of iron, but its physical and chemical characteristics cause difficulties in smelting; efforts are being made to overcome these difficulties, however, by drying and briquetting the sludge, either alone or mixed with coal.

Residues from the dry process are being used in gas purification, but the sludge from the Bayer process is not suitable for this application, as the iron is present as ferric oxide, which has little absorptive power. Another use for red sludge is in the manufacture of pigments; for this purpose it is dried, calcined at low temperature, washed to remove soluble matter, and redried. The pigment so obtained is not hygroscopic, and is not attacked by sea water or by a number of acids and alkalis in the cold. The colour resembles that of red lead. Other uses include those in glass manufacture and in ceramics to produce brown colours. It is noteworthy that The British Aluminium Co., Ltd., successfully market the red sludge from their plants.

Forthcoming Meetings

INSTITUTION OF MECHANICAL ENGINEERS.

March 25. "Exhaust Systems of Two-Stroke Engines," by H. O. Farmer, M.C., B.Sc.

April 1. "Glass Silk as a Thermal Insulator," by S. Palmer.

April 8. Report of the Sub-Committee on Tungsten Carbide Tools. Presented by Professor Dempster Smith, M.B E.

INSTITUTE OF MARINE ENGINEERS.

April 12. "Materials for High Pressure Steam Conditions," by Dr. R. W. Bailey.

INSTITUTE OF METALS.

BIRMINGHAM SECTION.

March 31. "Deep Drawing Problems," by Dr. J. D. Jevons.

April 14. Annual General Meeting. Address by W. F. Brazener (Chairman).

LONDON SECTION.

March 31. Annual General Meeting and Open Discussion.

INSTITUTE OF BRITISH FOUNDRYMEN.

BIRMINGHAM BRANCH.

April 1. Annual General Meeting. Short Paper Competition.

EAST MIDLANDS BRANCH.

March 26. Annual General Meeting. Summary of the Series of Papers presented during the Session, by H. L. Sanders.

LINCOLNSHIRE SECTION.

April 4. Annual General Meeting. Short Papers.

LANCASHIRE BRANCH.

April 2. Annual General Meeting. Presentation of Papers of Second Prize Winners in Sections I and II of the "Coronation" Competition.

LONDON BRANCH.

April 6. Annual General Meeting. "Sources of Information," by V. C. Faulkner, F.R.S.A.

MIDDLESBROUGH BRANCH.

April 22. "Steel and Alloy Castings," by J. E. Mercer and D. K. Barclay.

NEWCASTLE-ON-TYNE BRANCH.

March 26. Short Papers. Annual General Meeting.

SHEFFIELD BRANCH.

April 7. Annual General Meeting. "Steel and Alloy Castings," by J. E. Mercer and D. K. Barclay.

BRISTOL SECTION.

March 26. "Pattern Shop Practice," by T. R. Harris. Annual General Meeting.

International Engineering Congress, Glasgow, 1938

A number of engineering societies have decided to co-operate in organising an International Engineering Congress, in Glasgow, to be held during the progress of the Empire Exhibition, Glasgow, thus taking advantage of the attendance there of the vast number of engineers from distant parts who will doubtless then be in the city. A very representative General Committee has been formed, with the Rt. Hon. Lord Weir, P.C., G.C.B., as President.

The Congress will be held from June 21 to 24 inclusive, and during these dates an interesting programme has been arranged. During the technical sessions addresses will be delivered by outstanding authorities on each branch of engineering, and visits to works arranged, appropriate to the interests of these branches.

Membership of the Congress will be open to members of any recognised technical society. A fee of £2 5s. will be payable by each member, and £1 15s. for an accompanying lady, which will include attendance at Congress, excursions, receptions, etc., admission to the Exhibition, and volume of proceedings for each member. Those interested should communicate with Mr. P. W. Thomas, Hon. General Secretary, 39, Elmbank Crescent, Glasgow, C. 2, for a detailed programme.

Mr. W. F. Prentice, of Dorman, Long and Company, Limited, Middlesbrough, has been appointed chairman of the Basic Pig-iron Producers Association.

METALLURGIA
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Science and Technical Progress

The Need for Information on Technical Operations

IT is sometimes said that the fashions of human thought sway to and fro, and in many respects repeat those of ages past, so as to leave an impression that what is called progress should rather be termed change. But, side by side with these tide-like variations there is a steady and irresistible advance in that which sets the frame-work of our individual and social existence—the intimate knowledge of the world in which we live and its capabilities, all of which is summed up in the word science. One age may be more successful than another in adding to the store or in making full use of that which exists, but the totality of the knowledge of the world is ever on the increase. Science, thus understood, is ever changing the world in which we live by making us more fully acquainted with the properties and potentialities of that which we find there, and there is no doubt that science will continue to offer mankind the power to accomplish more than at present can be imagined, the question is whether mankind will apply the power.

To a very large extent the application of science to the needs of mankind is dependent upon the distribution of accurate and ordered information, and also upon the ability to use it to the best advantage. Many scientific and technical organisations are increasing the totality of knowledge and increasing the store of accurate and ordered information, with a view to a more systematic planning of industry. The Institute of Metals, as pointed out by Dr. Desch in his presidential address at the recent annual meeting, is such an organisation; it makes possible the full and frank exchange of technical knowledge and helps to spread information, not only by its collection of facts, but also by fostering a spirit of co-operation in the industry.

On the question of papers, offered to an institute of this type opinions must necessarily vary considerably. It is probably true, as Dr. Desch states, that the greater number of papers offered should come from research laboratories, and be written by scientific workers, because so many investigations are frequently necessary to establish one fact, and, since a report of the investigations and of the results must be made for future use, its preparation as a communication to the public is usually less difficult than the preparation of a paper describing some technical operation. Exceptions must be made where authors of scientific papers have prepared them in the simplest language consistent with accuracy. This is much more difficult than is at first apparent, yet there is an increasing need for papers in which the results of investigations are made known to industrialists whose experience is on the practical side. The time-log between the establishment of a fact and its application in practice is much too long, and it is gratifying that some effort is to be made by the Institute to reduce the gap between the ideas of the research worker and the apprehension of the works manager or technician.

It has been suggested to us that the majority of scientific papers which are approved by the Publication Committee should be published and only written discussion considered. There is much to be said for this course, especially, if it enabled papers on technical operations to be read and discussed at meetings with a view to the more rapid dissemination of the methods for applying the results of scientific discovery. It should not be overlooked that many scientific investigations are of a specialist character and even at a general meeting only a few members can profitably discuss the results. The same may be true of a paper dealing with some technical operation, such as, for instance, the development of continuous casting of rods and bar shapes from a melt by withdrawal through a die or forming chamber, but it would probably claim the interest of a greater number, and cause practical men to take part in discussions.

There are many in charge of technical operations quite capable of preparing informative and useful papers, but, while firms may, and frequently do, give permission to members of their laboratory staffs to prepare a paper for presentation to some institute, they do not show the same desire to give widespread information on important technical operations carried on in their works. This is not altogether surprising, because much time and expense is generally involved in experimental work on a production scale before a particular manufacturing technique is developed. Although it is true that old prejudices are breaking down, keen competition exists between manufacturers, and the results of big-scale investigations, which would form the basis for informative papers, are naturally applied in the works concerned, and much time may elapse before it is considered safe to issue a record of the work to the public. The technical man also suffers another handicap not usually experienced by members of a laboratory staff; as a rule, his time is fully employed on production, his hours are longer, and the preparation of a paper must necessarily be done in his spare time, obviously, therefore any marked expansion of industry reduces the opportunities for preparing technical papers of this type.

That there is a need for such papers is clear from casual conversations we have had with many members of the Institute of Metals; some, in fact, assert that they had ceased to take special interest in the annual meetings because too much attention was given to matters of an abstruse character, which had only a remote connection with industry. In view of this opinion, it is gratifying to note from Dr. Desch's address that papers having a direct practical bearing will be welcomed by the Institute, and that aid will be willingly given, if needed, in putting material into a form suitable for publication. It is probable this could be assisted by following up scientific investigations with more detailed information regarding their application to industry resulting from service experiments. For such work members with a metallurgical training and sound practical training of particular branches of industry would be admirable. This method would tend to reduce the gap between science and practice, and would materially assist in speeding up the application of the results of scientific investigations. Such a policy has long been in operation in large works capable of supporting their own research laboratories, but the Institute might well use its facilities to foster the same policy for the benefit of a wider public and its own members in particular.

Science has done much for mankind and will continue to offer mankind the power to accomplish more, but it is for organisations like the Institute of Metals to provide facilities to enable mankind to apply the powers.

The Leipzig Fair

GERMAN industrialists refer to the Leipzig Fair as one that has benefited by one hundred years development ; certainly the Fair has now extended well into the second half of a hundred years—a testimonial to trade and industrial development, both in respect of German productions and those of the many other manufacturers from other countries who have been represented at all or some of the annual Fairs.

During this time not only has industrial production changed, but with it has been a change of market conditions. Buyers have been influenced in some cases by the development of design and the modification of prices resulting from improved manufacturing facilities—and those facilities have been improved through the efforts of almost every aspect of the metallurgical industries—and, in many other cases, manufacturers have designed and produced their goods after analysis of specific requirements, fitting the product to the market.

For a time the Leipzig Fair was one where stock was displayed and sold. To-day, it has become a vast exhibition for the display and discussion of manufactures and products. Modern methods, and modern business practice, have combined to allow purchasers to place orders after inspection of articles displayed, confident that the goods they receive would be comparable with those inspected. Previously, goods had often to make a roundabout journey to Leipzig, be exhibited and stocked at the Fair, and sold on the spot. With the current policy of making this an exhibition and not a saleroom, goods pass in logical sequence from the point of production direct to the buyer—which is more in accord with the policy behind many of the exhibitions held in this country.

Rolls on view by Fried, Krupp, Grusonwerk, A.-G.

This year's Fair proved quite interesting from a metallurgical point, particularly with respect to machines designed to facilitate work in the metal producing industries. Firms like Demag, which specialise in plant and equipment for the iron and steel industries, find it difficult to display the wide range of work for which they are noted. Apart from size, much of the plant built is designed for a particular works and it would be absurd to attempt to erect similar plants as exhibits, but many visitors were especially interested in some fine models of steel works plant Demag's have designed and installed in various works. Mention may also be made of Fried, Krupp, Grusonwerk A.-G., whose exhibits included special rolls for steel mills.

The exhibits of Siemens-Schuckert were very comprehensive, the main stand in particular giving a general urvey of the present state of electrical engineering and specially on the advances made during the year. The most important products exhibited included a new oil-free expansion circuit breaker for 60,000 volts. Four smaller circuit breakers designed on the same principle for 10,000 volt. are also shown. Protective and remote-control practice is shown by the latest type of panel ; an apparatus for low-tension switching and measuring ; electric drive practice, etc.

In the machinery section, considerable interest is attached to the machines exhibited by Schiess-Defries A.G. A crank-pin turning machine attracted much attention in view of the fact that the crankshaft is stationary while the tools revolve. These machines are special types for roughing and finishing the pins and webs of heavy single- or multi-throw crankshafts. Here are a few of the many outstanding features : Direct electric drive by flanged motor ; reliable and effective oil circulation system with pilot lamps for the lubrication of the guideways of revolving ring ; cascade method of lubrication for all driving and feed gears ; continuous radial feeds to the tools ; quick power traverse in all directions ; safety couplings for the gears of the longitudinal and transverse movements ; limit switches for the traverse motors ; push button control. The revolving ring of the model shown was of 1,250 m/m. inside diameter.

Another interesting machine shown by this firm was a cutter-head grinder. This machine is employed for the automatic grinding of milling and cutter heads, cylindrical or slab milling and forming cutters of all kinds ; no auxiliary means being required. Both face and peripheral cutting edges can be ground, and the necessary chamfering and radiusing done. The moving gears of this machine are all arranged in the machine in dust-proof casings, but are easily accessible. The periodical indexing movement of the main spindle, i.e., of the cutter to be ground, is derived from a flanged motor and transmitted through a stepless regulating gear in such a way that the movement is disconnected during the grinding operation, the blade to be cut being used as a stop. The grinding zone and stroke of slide can be adjusted according to requirement. The grinding wheel fixture together with the grinding motor can be adjusted both vertically and horizontally to suit the position of cutting edges.

Starting of Biggest Blast Furnace in U.S.S.R.

THE most powerful blast furnace in the U.S.S.R. and in Europe, will be blown in when Zaporozhstal (Zaporozh Steel Works) commences to operate some of its principal units. Producing 1,600 tons of pig iron a day, the furnace will turn out more pig iron a year than was produced, on the average, by the 20 blast furnaces in operation in pre-war Russia. Of a new type, the new furnace has a volume of 1,300 cubic metres. It incorporates the latest developments and every operation is fully mechanised.

Intensive work is also in progress on the completion of the Zaporozhstal sheet mill, the testing of which will soon be undertaken. Claimed to be the world's largest sheet mill to be put into operation, its powerful blooming mill will transform annually two million tons of steel ingots into slabs for sheet rolling. Other plant which will shortly commence working in this mill are a rolling mill for producing medium size steel, a thin sheet steel rolling mill with reheating furnaces, mills for rolling cold steel, presses and other machinery.

The output capacity of the new sheet mill will be 1·3 million tons of finished sheet steel a year. Of this quantity, 900,000 tons will be high-grade thin auto-tractor sheet steel suitable for deep stamping. The electric motors of the mill have a capacity of 50,000 h.p.

Large electric furnaces of the Mige system have been installed in the melting shop of these works, while in its tool steel shop are the powerful electric furnaces and fully mechanised rolling mills. It is claimed to be the most powerful unit in Europe for the production of carbon and alloy steels for tools and instruments.

Special Steels and their Application to Engineering and Shipbuilding

By T. SWINDEN, D.Met.

A very comprehensive survey of metallurgical developments of recent years, with particular reference to the problems facing shipbuilders and marine engineers, is given by the author in a recent paper before the North-East Coast Institution of Engineers and Shipbuilders. Dealing with carbon steels, low-alloy steels and wrought iron, the author discusses special characteristics such as embrittlement, weldability and corrosion. This leads to a section on the more highly alloyed steels of special interest in engine construction. Special attention is given to the subject of fatigue and notch sensitivity; surface hardening is also considered, and a section is devoted to the properties of various steels at elevated temperatures. The paper is so extensive that here it is only possible to present some of the features.

Carbon Steels, Wrought Iron and Low-Alloy Steels

UNALLOYED mild steel finds a large market in the realm of shipbuilding and marine engineering, and it is unnecessary to describe its general properties. Perhaps the most noteworthy development in recent years has been to show that toughness, as judged by the Izod impact test (in the normalised or heat-treated condition), is related to steelmaking procedure. Swinden and Bolsover[1] have shown that steel may possess widely different characteristics, believed to be due to the effectiveness of deoxidation in steelmaking. The effect is more pronounced in plain-carbon and low-alloy steels than in highly-alloyed steels, and while other properties remain essentially similar, the toughness and resistance to various forms of embrittlement are greatly improved by providing a fine "inherent grain size," as determined by the McQuaid-Ehn method.

Free-cutting Steel.—Rapid machining is an essential feature of automatic machine production, and steels specially designed to have free-cutting properties have long been used. Formerly they were characterised by brittleness and lack of reliability. To-day they are standardised—B.S.S. No. 32, 1935—and Grade IV in this specification is a highly specialised product. It differs from the earlier types which contained about 0·1% each of sulphur and phosphorus, in that phosphorus is normal——about 0·05%—and sulphur higher—0·2 to 0·25%. There is much more than analysis requiring control to ensure the desirable regularity of product. The selection of raw material and furnace operations are, in fact, given the same meticulous care as a highly-alloyed steel. The steel responds readily and satisfactorily to case-hardening.

Corrosion.—On the subject of corrosion reference is made to a paper by W. E. Lewis,[2] who concluded that the conditions under which mild steel is exposed to corrosion have a greater effect on its corrodibility than minor variations in either its chemical or its metallurgical constitution, so that the choice of the most suitable method of protection remained of paramount importance in preventing the corrosion of ships' hulls by sea-water. He expressed the view, however, that the use for marine work of steels containing copper, either alone or in conjunction with a small amount of chromium, was worthy of consideration, although there were differences of opinion as to the practical advantages that would accrue thereby.

Although the superiority of copper-bearing steel as regards resistance to atmospheric corrosion, especially in industrial areas, is well marked, and its superiority in resisting attack by certain types of weak acids is overwhelming, there is little definite evidence that copper-bearing steel is superior to ordinary steel in its resistance to corrosion in sea-water. Actual service data are conflicting. It is interesting to note, however, that tests carried out in Workington harbour, under the direction of the author, with an ordinary mild steel, a mild copper-bearing steel, a high-tensile steel and a high manganese-copper steel, gave results which indicated the superior resistance to corrosion of the high manganese-copper steel. It is, of course, important to bear in mind the conditions under which the observations were made. Notwithstanding all the work that has been done, the problem of corrosion is so complex as to make it impossible to generalise, and nothing but large-scale practical tests can as yet be taken as reliable data on this subject.

Weldability.—On the question of weldability it is doubtful whether any serious problem exists to-day in the welding of mild steel. For many years the author has been interested in the manufacture of steel for electrodes, and it is, of course, readily demonstrable that small differences in composition and radical differences in the type of mild steel have a profound effect on the suitability for electrode manufacture. However, in a further attempt to investigate the effect of these differences on mild steel as parent metal, entirely negative results were obtained in using all the well-known methods of welding. It is recognised, however, that there are certain problems still requiring solution in the welding of what are generally termed high-tensile or low-alloy structural steels. There is a large choice of steels within this designation, and if it is not required to exceed a tensile strength of, say, 35 tons, it is possible to obtain reliable steels with a low carbon content, the welding of which can be carried out with reasonable satisfaction. In the somewhat higher range of tensile strength—37 to 43 tons—problems arise through the production of the hardened zone behind the weld, which is often accompanied by cracking. Dealing with metallurgical aspects, investigations have been carried out in many directions on the usefulness of certain additions which have the property of inhibiting the hardening effect normally attributable to carbon. Titanium may be regarded as a typical inhibitor, and it has been used in many directions. In this particular application, the author has worked out a ratio of Ti : C, which substantially suppresses the hardening behind the weld and at the same time produces a steel having excellent physical properties. The analysis of such a steel is given as:

C.	Mn.	Si.	S.	P.	Cu.	Ti.
0·15	1·44	0·16	0·03	0·04	0·20	0·37

Physical Properties.—This subject is considered under three main headings, namely: Ship-plates, boiler-plates, and bars and forgings for constructional purposes. No reference is made to the properties of standard-quality mild steel used in the hull construction of a ship. Development of so-called high-tensile or high-elastic-limit steels is now no longer a novelty. The higher tensile properties

[1] "Controlled Grain Size in Steel," *Journ. I.S.Inst.* No. II., 1936.
[2] "Protection of Ships' Hulls Against Marine Corrosion," Trans. N.-E.C. Inst. E. and S. Vol. 52. P. 127, 1936.

accompanied by higher values for the limit of proportionality and yield point, are the main appeal of these steels, and although it is held in some quarters that greater corrosion resistance is an accompanying asset, opinions differ as already stated, concerning corrosion problems. It has been known for many years that phosphorus, under certain conditions, improves the tensile strength and corrosion resistance, and, particularly in America, certain brands of high-tensile steels, which contain phosphorus up to say, 0·2%, have been supplied in considerable quantities for this purpose. The author's view, following a careful study of the subject and considerable research work, is that it is preferable, if possible, to avoid resort to phosphorus.

Where a commodity must be kept within reasonable limits of cost, full use should be made of the cheap alloying elements, such as manganese, silicon and copper. Chromium is also very useful, but, in the author's experience, not essential. While high-silicon steels were among the first of the high-tensile types to be developed, they are not particularly popular, because, of the available alloying elements, silicon is the least effective in increasing strength, and large additions undoubtedly add to production difficulties. Nickel is, of course, a most valuable alloying element, but it is comparatively expensive. It was, therefore, a very normal metallurgical development to increase the manganese content, and introduce some years ago the Admiralty " D " type of steel. The addition of a small amount of copper to this steel further improves the physical properties, and, at least under many conditions, definitely improves its corrosion resistance. The manufacture and manipulation of this type of steel is a straightforward proposition, and by suitable adjustment of the balance between the carbon, manganese and copper, a very useful steel is evolved which can be taken as a basis from which to compare the numerous other types of high-tensile steels that have been proposed.

Before proceeding to consider the physical properties of alloy steels supplied mainly in the form of bars and forgings, the author thought it appropriate to make some comments on certain more special aspects such as embrittlement, fatigue, and notch sensitivity.

Embrittlement.—This term has been applied to a number of completely dissimilar phenomena. When mild steel is strained and tested after release of the stress, the impact value is reduced, and if the steel is reheated to a comparatively low temperature when in the strained condition, it can readily be shown that the impact value is usually reduced very considerably. This is known as *strain-age embrittlement.* The phenomenon has long been known. Data contained in the paper by Swinden and Bolsover on " Controlled Grain Size," show that in a mild steel of inherent fine grain characteristics, which is obtained by the use of strong deoxidisers, embrittlement can be almost completely suppressed. This fact has been confirmed in both open-hearth and acid Bessemer steel. As data on this point concerning acid Bessemer steel have not been published elsewhere, the following is included by way of example. The steel was a typical mild acid Bessemer steel of the following composition :

C.	Mn.	Si.	S.	P.	N.
0·095	0·85	0·090	0·046	0·042	0·016

One portion of the blow was cast normally and had a McQuaid-Ehn grain size of 3 to 4, and the remainder was specially deoxidised with aluminium, and had a grain size of 7. The tests on ⅞-in. diameter bars, normalised 920° C., were as follows :—

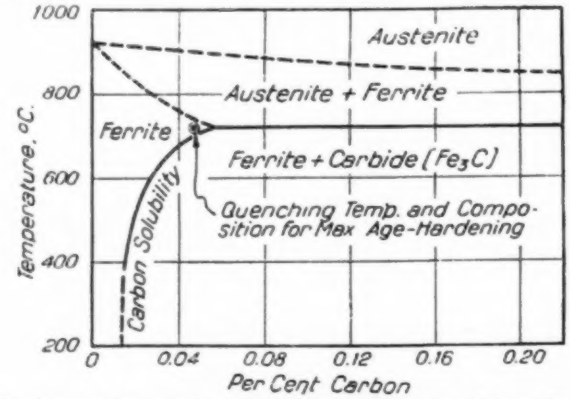
Grain size.	Yield-point. Tons/sq. in.	Maximum stress. Tons/sq. in.	Elongation. % on 2 in.	Reduction of area. %.	Izod impact. Ft. lb.
3—4	20·0	28·6	40·5	68·0	91
7	24·0	27·6	43·0	75·6	96

Strain-age-embrittlement tests, carried out according to standard procedure by straining 15% followed by reheating for 30 mins. at 250° C., gave the following results :

Grain size.	Treatment.	Izod impact figures.		
		Ft. lb.	Average.	% drop.
3—4	Normalised 920° C.	86, 94, 95	92	—
	,, ,, Strained 15%	30, 20, 56	36	61
	,, ,, ,, ,, 250° C. ½ hr.	8, 5, 5	6	93
7	Normalised 920° C.	94, 100, 99	98	—
	,, ,, Strained 15%.	81, 85, 90	85	13
	,, ,, ,, ,, 250° C. ½ hr.	80, 79, 83	81	17

These data are in line with those obtained with steel made by the open-hearth process. Although a good deal of information has been published on the same lines, it is doubtful whether its significance is fully realised.

The term *quench-ageing* relates to the hardening usually accompanied by a reduction in toughness which develops on resting at room temperatures or slightly elevated temperatures after quenching. It is to be explained on the ground of " precipitation hardening," and it follows that the most pronounced effect is obtained on a carbon steel when the carbon is of the order of 0·04% quenched from about 700° C., as shown in the accompanying diagram. This is taken advantage of for commercial purposes in the production of spring wire and, on the other hand, it can be a source of trouble in other directions, unless safeguarded against. Attention is drawn to a new feature, in that fine-grain steel produced by suitable additions of aluminium, does not embrittle to any appreciable extent.



Portion of iron-carbon constitution diagram with carbon scale extended to emphasise the solubility of carbon in alpha iron and the age-hardening potentialities of the system.

An entirely different form of embrittlement, which is not so widely recognised, is that termed annealing brittleness. It refers to loss of impact value when mild steel is strained, followed by reheating to temperatures in the neighbourhood of 700 to 800° C. Attention is drawn to this by Andrew and Hudspeth[3] and in a later paper by Andrew, Jeffrey and Johnson.[4] A low-carbon 1·5% manganese steel is shown to be immune from this embrittlement. The author has carried out considerable work on this subject, and is able to confirm these findings, although it has been found that even the manganese steel can be put into a brittle condition when cooled from certain temperatures with a critical rate of cooling.

The subject of the so-called *caustic embrittlement*, in the case of boiler plates, has taken a new orientation during the last few years. It now seems that the description is somewhat of a misnomer, and that it would more properly be described as intercrystalline failure under stress due to chemical action, not necessarily that of caustic soda, or the alleged embrittlement by hydrogen arising out of the action of caustic soda on iron.

Fatigue and Notch Sensitivity.—The various aspects of fatigue, including corrosion fatigue and notch sensitivity, have been dealt with so thoroughly by MacGregor, Burn

3 Inst. Mining Eng., January, 1934.
4 Safety in Mines Research Board, Paper 100,

and Baron,[5] and Hauttmann,[6] that the author has little new information to add. The problem remains one on which further data required to be accumulated, particularly in the direction of relating methods of laboratory testing with the larger masses actually used in service, and to the fundamental data relating to the initiation and rate of propagation of a crack in fatigue with other characteristics of the steel. In an effort to add further imformation the author has plotted the limiting fatigue stress and notch sensitivity as determined on a variety of steels from 20 to 70 tons tensile, alongside the maximum stress, yield stress, elongation and reduction of area. The figures show that the ratio of the fatigue stress to the maximum stress on a plain specimen is fairly constant, and that, notwithstanding an increased notch sensitivity of high-tensile material, the actual fatigue limit on a notched specimen increases with the tensile strength in this series of tests.

It can readily be shown that there is no relationship between the fatigue stress or notch sensitivity and the Izod impact test. The simplest example is to take a nickel-chromium steel in the temper-tough and temper-brittle condition. The data given in the paper shows that, notwithstanding a difference between 55 and 7 ft. lb. in the Izod impact value, there is no significant difference in the fatigue limit, the fatigue ratio or the notch sensitivity.

Higher-Alloyed Steels

It is difficult to convey in a useful form the basic information that is necessary to bring out the special characteristics of any particular steel. The author has endeavoured to do this by including an appendix giving a set of typical tensile and impact tests on a series of alloy steels scheduled in ranges of tensile strength. All the values given are the results of actual tests. Attention is directed to the grain size which is reported in each case, and the author emphasises that, in his opinion, no comparative data to-day are complete without this information. No attempt is made to correlate each of these steels to special purposes, attention is, however, directed to significant developments of recent years. There has been a definite tendency to make use of cheaper alloy steels, relying on a suitable manganese content with or without small additions of molybdenum and, in some cases, of nickel. Another development is steel containing approximately 3% chromium, and 0·5% molybdenum which, having a suitable carbon content, has a remarkable combination of properties and is of great utility. It also has, where required, the advantage of responding well to nitriding and to casehardening.

A request was made some time ago for a steel with 150 tons tensile strength for aero-engine connecting-rods and, as a matter of interest, the results of tests—on commercially-produced steel—are recorded. The steel is a Ni-Cr-Mo-Va steel ; test samples were treated in test-piece size by oil hardening from 830° C., and tempering 220° C. The average of three test-pieces gave a maximum stress of just over 150 tons per sq. in.

Surface Hardening

Carburising.—Case-hardening by carburising the surface followed by quenching, is still the most common method of obtaining a high surface hardness. A table gives a set of typical data on five well-known types of case-hardening steel—carbon steel, 3% nickel steel, 5% nickel steel, nickel-chromium steel, and nickel-chromium-molybdenum steel. The relative response to carburising of these steels has been determined over a range of temperatures and carburising times. An alternative quality of case-hardening steel, containing lower nickel together with chromium and molybdenum, is capable, in the author's opinion, of meeting the tests usually called for in 5% nickel steel, and it is definitely less susceptible to mass effect.

Cyanide Hardening.—Apart from the use of a cyanide bath for camparatively deep carburising and a combination of carburising and nitriding known as "Chapmanising," the cyanide bath has been used with advantage for giving a final hard surface, particularly to gear steels of the direct-treatment type—i.e., not case-hardening steels as such. This has obvious advantages and, in the view of the author, the practice is likely to develop.

The Shorter Process.—This is now well known, and relies on the rapid quenching of the surface after heating in a flame travelling along the surface of the work. Although originally only applied to ordinary carbon steel, it has been shown that alloy steels can be treated by this method, and it appears to be well suited to the treatment of gears. It has been developed to a considerable extent in Germany for the hardening of pins and journals of crankshafts, by what is known as the Shorter Double-Duro process.

Tocco Surface-Hardening Process.—This later process has considerable appeal from a scientific point of view, relying as it does, on the use of a high-frequency current for heating the surface of the part to be hardened, followed by rapid quenching by water supplied through holes in the inductor coils. The controlled precision by which this process can be carried out has obviously a great attraction, and it is being used regularly for the hardening of the pins and journals of crankshafts. A chromium-molybdenum steel is regularly being used for this purpose. The developed hardness is still, it is understood, in the region of 600 to 650 Brinell, which represents a limitation in some cases, but the process has great possibilities owing to the precision with which it can be applied.

Nitriding.—There is no longer any novelty about the nitriding process, which consists of heating the steel in an atmosphere of ammonia at approximately 500 ° C. The ammonia is dissociated and nitrogen enters the surface of the steel, producing intense hardness due to the formation of nitrides. Several steels have been introduced for this purpose and the tendency has been in the direction of reducing and finally eliminating aluminium and, at the same time, increasing the molybdenum content. The latest development is a 3% chromium, 0·5% molybdenum steel which nitrides readily and gives a hardness which is adequate for most purposes.

Steels for Use at Elevated Temperatures

Assuming a steel, for use at elevated temperatures, to be capable of fabrication into the desired article in a workmanlike manner—including welding if necessary—it must possess the following characteristics :

1. Adequate permanence of dimension together with satisfactory physical properties both at normal and service temperatures.
2. Adequate resistance to deterioration by scaling and corrosion (particularly pitting).

The strength falls, of course, with increase of temperature, but, in addition, the steel fails to behave as an elastic body and begins to show "creep" characteristics when a certain temperature (depending upon the temperature and prior treatment) is exceeded. It is generally assumed that the maximum temperature beyond which ordinary mild steel is inadequate, is somewhere about 800° F., the actual temperature depending on the stress to be withstood. The inadequacy first manifests itself by creep, and later by scaling, as the temperature of service is raised.

The determination of creep properties is a lengthy business, but systematic work in laboratories throughout the world is not only making data available for the guidance of engineers, but is supplying information on which a more fundamental conception of the creep phenomenon can be based. There is no alternative meantime to the "long time" time-deformation data by which to determine the total deformation that may take place in a given time, but there has been evolved a number of "short-time" tests which do give relative creep resistance, and attention is directed to the Barr-Bardgett apparatus.

From among the mass of most valuable research data, the author mentions one hypothesis which interests him particularly. This arises in the work of A. E. White and C. L. Clark (respectively, Director of Engineering Research

5 Trans. N.-E.C. Inst. E. and S., January, 1935.
6 Trans. N.-E.C. Inst. E. an S. January, 1936.

and Research Engineer of the University of Michigan), and R. L. Wilson of the Timken Steel and Tube Company. It refers to the "equi-cohesive temperature" hypothesis, which, stated briefly, says that below a certain temperature, strain-hardening predominates and stresses of appreciable magnitude can be withstood without continuous creep. At temperatures above this, the rate of recrystallisation will exceed the strain-hardening rate and continuous creep will occur under very low stresses.

While the view that for each composition there is a "critical temperature" cannot be accepted, yet it is, in the author's opinion, sound to regard creep as a resultant of the two factors—strain-hardening and recrystallisation. There does not necessarily exist a critical temperature for either factor, but there is a range of temperature within which the effect of one will diminish and the other will predominate. Such a conception assists in understanding the readily demonstrable fact that the order of merit as to rate of creep may be reversed for two steels when tested respectively, at say, 850° F. and 1,050° F.

We are all indebted in particular to Dr. R. W. Bailey for his various publications dealing with the application of creep data to engineering design, but it will be admitted that we still require authoritative guidance in practical terms on the subject of design stress data at elevated temperatures. The N.P.L. is, of course, continuing its researches, under the auspices of a Committee of the British Electrical and Allied Industries' Research Association, to this end.

One characteristic was referred to which has received considerable attention, namely, the embrittlement developed in certain steels during prolonged exposure to service temperatures. It was Dr. R. W. Bailey who first drew my attention in 1928 to some work he had done showing that certain steels, which were generally considered to be free from the well-known "temper brittleness," did in fact embrittle very seriously when subjected to repeated heating to about 500° C. under stress. Considerable research was immediately carried out on the response of various types of alloy steels to this treatment, which quickly led to the conclusion that it was desirable to exclude nickel. Since that time, many interesting and exhaustive researches have been reported. Lea and Arnold[7] and W. E. Goodrich[8] have provided very full data. Both find that a mildly-alloyed chromium-molybdenum steel is the most resistant to embrittlement.

The foregoing work has been done mainly at temperatures of 450° C. and above, and as temperatures somewhat lower than this are likely to interest marine engineers, similar tests have been carried out at temperatures of 350, 400 and 450° C. (662, 753 and 842° F.), and, as a matter of interest, the results are included in the paper. The author adds that they will be dealt with in greater detail elsewhere in the near future, together with an investigation as to how this type of embrittlement bears on "temper brittleness," or the susceptibility of steels to relative brittleness if cooled slowly from the tempering temperature during heat-treatment. It may be stated briefly that the susceptibility to "temper brittleness" falls into the same order as the tendency to long-time embrittlement.

The subject of superheater tubes is selected as representing a specific problem occupying the minds of powerhouse engineers engaged in the installation of present-day power-hourse equipment, and one imagines the same problem applies, if to a less severe extent, in the case of marine boilers of special type. It is generally considered that with steam temperatures and pressures now obtaining, even well-killed mild steel is not good enough. It has long been recognised that the most effective way of improving the creep strength of mild steel is by the addition of molybdenum. An increase in the carbon content while raising the tensile strength in the cold, does not increase the creep strength at temperature; in fact, in certain low-alloy steels, it has a very definite reverse effect. Hence, the popularity of the well-known 0·5% molybdenum low carbon steel where high creep strength and ease of manipulation are desired.

The presence of molybdenum does not improve the corrosion or oxidation resistance and, incidentally, work at the N.P.L. has drawn attention to certain features, such as intercrystalline failure at high stresses, which has caused some uneasiness.

Another steel containing 0·25% molybdenum and 0·25% copper, has also met with considerable success, but research is centred largely around the 0·5% molybdenum with addition of chromium. This forms an extremely interesting and valuable series. Additions of chromium increase the creep strength up to about 1·1 to 1·4%, beyond which it declines. It has further been ascertained by research, that other constituents have an important effect on the creep strength, manganese to a certain extent and silicon very definitely. There is apparently an optimum silicon content relative to the other constituents in this direction. Work at the N.P.L. has also indicated the value of vanadium.

The problem to-day appears to be to find a steel to operate in the range 850° F. to 1,100° F., which has adequate resistance to creep and to internal and external scaling and/or corrosion, to be free from embrittlement, and to be capable of easy manipulation into tubes and fabrication into superheater elements, and finally, to be reasonable in price. A steel containing approximately 0·15% carbon, 0·8% chromium and 0·5% molybdenum, has been used in one important power station, operating at 1,950 lb. per sq. in. pressure, and a steam temperature of 932° F. Considerable attention is being directed at the moment to the possibilities of the well-known 4 to 6% chromium, 0·5% molybdenum steel, which is well established on account of its resistance to embrittlement by nascent hydrogen, and is a standard material in oil-refinery work, hydrogenation plant, etc. The author has a little difficulty in realising the advantages that this steel possesses as a superheater-tube steel. As this is a very live subject at the moment, it may interesting to quote in Table 12 creep data relative to this steel in comparison with mild steel, 0·5% molybdenum and the lower chromium-molybdenum steel.

TABLE 12.

BARR-BARDGETT CREEP TESTS ON FOUR TYPES OF SUPERHEATER TUBE STEELS.

No.	Type.	Analysis.					Condition.	Test tempera-ture.	Safe working stress.
		C. %.	Mn. %.	Si. %.	Cr. %.	Mo. %.		° C. (° F.).	Tons/sq. in.
1	Mild steel	0·12	0·55	0·21	—	—	Normalized 910° C.	500 (932)	1·1
2	½% Mo.	0·09	0·42	0·09	—	0·52	Annealed 910° C.	500 (932)	2·5
3	1% Cr—Mo	0·09	0·46	0·45	0·88	0·54	Normalised 910° C.	510 (950)	3·5
4	6% Cr—Mo	0·20	0·39	0·27	5·84	0·41	A.C. 950° C./A.C. 750° C.	500 (932)	1·6

The author regrets that his own "long-time" creep data are not yet available on samples of these particular steels, but information given in the very excellent "Digest of Steels for High Temperature Service," issued by the Timken Steel and Tube Company, Canton, Ohio, puts the steels in the same order of creep resistance as the Barr-Bardgett tests.

STAINLESS STEELS

Apart from the possible interest which the stainless steels may have for the marine engineer in connection with steam-raising plant, there are many directions in which these remarkable steels have not only attraction, but properties necessitating their use. The general properties of the stainless steels are too well known to need recapitulation here.

One use for which several varieties of stainless steel have been established for many years, is that of turbine

7 Inst. Mech. E. December, 1935.
8 *Journ. I.S.I.* No. 1, 1936.

blading. Three general types are well known, namely, 13% chromium, 18/8 chromium-nickel, usually containing special additions, and the 35/12 nickel-chromium, again usually containing small additions of other special elements. The serviceability of the 35/12 nickel-chromium alloy is very firmly established. It suffers the disadvantage, however, of being difficult to manipulate and machine, and of being very expensive. Messrs. Samuel Fox and Co. Ltd. have concentrated on the development of a steel of the 18/8 chromium-nickel type, being a special modification of "Silver Fox 22," having a low carbon content and a suitably balanced composition to provide the necessary creep strength, resistance to corrosion and erosion, complete freedom from strain-age-embrittlement, while, at the same time, having the advantage of being relatively easy to machine. There is every reason to believe that such material is entirely suitable for impulse turbine blading. The 13% chromium low-carbon quality is, of course, commonly used for the high-pressure and low-pressure reaction blades.

Finally, we have the so-called heat-resisting steels, which, generally speaking, are also stainless, and which are essential for such parts as baffle plates, superheater slings and supports and other uses where metal is exposed to furnace gases at very high temperatures. Here again, there is a complete series of steels designed to meet ascending limits of temperature, and each having its own particular characteristics. Up to 800° C., the 13% chromium steel will resist scaling, has good strength, and is immune from deterioration by sulphur-bearing gases. If the chromium is increased to about 20% the limiting temperature is raised to about 1,000° C. By increasing the chromium further to about 28% the steel can be used continuously at temperatures up to 1,150° C., although, due to their being "ferritic," the high-chromium steels are comparatively weak at temperature.

Where greater strength as well as maximum scale-resistance is necessary, 20% chromium, 8% nickel with 2% tungsten is recommended, as providing a useful combination of desirable properties, and finally, where it is necessary to work up to such temperatures as 1,150° C. with really substantial strength, one adopts a nickel-chromium steel of more complex composition.

There is another class of heat-resisting steels of which aluminium is an essential constituent, and which may contain also suitable amounts of chromium and silicon. Under oxidising conditions, their resistance to scaling is extraordinarily high. The most resistant alloys do not, however, possess as good physical properties as do the better-known chromium-nickel and nickel-chromium alloys, and they do not lend themselves so readily to hot and cold manipulation. It is in this field, however, that some noteworthy developments in heat-resisting materials may be looked for. Efforts are also being made to take advantage of the well-known "precipitation hardening" effect produced by certain alloys to provide the superior strength at temperature now being demanded.

Aluminium Bronze Gravity Diecasting

By Dr. Arthur Street

IT would be platitudinous or even untrue to call aluminium bronze the "Cinderella of the yellow-metals," but it is certain that the well known difficulties of producing satisfactory foundry castings in this alloy have caused users to be slow in recognising the merits of aluminium bronze in its diecast form. In this condition the alloy has a tensile strength of the order of 35 tons per sq. in., elongation between 25 and 35% and a Brinell hardness of about 120; this is coupled with a high resistance to fatigue.

Not only does the alloy maintain its attractive "10-carat gold" appearance, but it displays resistance to most forms of corrosion. Consequently, there are many industries which are applying aluminium bronze die-castings for high duty components which must combine strength with good appearance. Aluminium bronze, usually of 10% composition, has been gravity diecast in this country since about the year 1922—that is the time when Stockdale published his study of the constitution of the copper-aluminium alloys.*

From the equilibrium diagram of the copper-rich alloys it can be seen that the melting point varies within a narrow range, it is 1,083° C. for pure copper, decreasing to 1,030° C., at the composition 9% aluminium. With increasing amounts of aluminium the melting point gradually rises to a second maximum at 1,050° C., for 12·4% aluminium. The solidification temperature remains extremely close to the liquidus and the maximum freezing range is about 10° C., at the 7% alloy.

It is important to realise that the constitution of these alloys varies notably with the rate of chilling. The 10% alloy, chill cast, has a structure of alpha solid solution plus the beta phase, yielding an optimum combination of toughness and strength, definitely superior to the properties of the same alloy in the more slowly cooled foundry cast condition. Further additions of aluminium

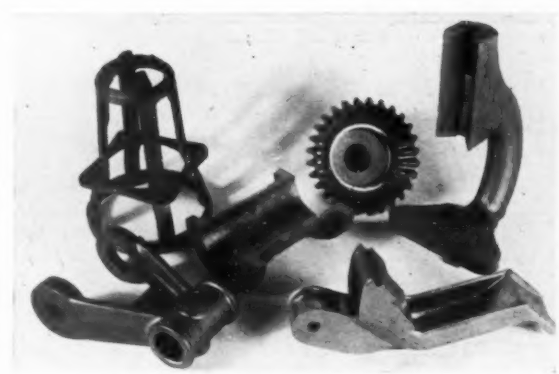


Fig. 1.—Group of aluminium-bronze gravity die-castings.

reduce the quantity of alpha present and lead to embrittlement due to increased beta; beyond 12·4% some of the brittle delta phase is formed.

For safety's sake the composition which is diecast should not be allowed to exceed 10·5% aluminium and close check must be maintained in the melting and mixing of the alloy, for if a diecasting should accidentally contain of the order of 12% aluminium it will be extremely brittle. In the best regulated communities an occasional mistake can sometimes be made but if the aluminium content rises too high the colour of the diecasting comes noticeably whiter and when struck, the alloy sounds dull as compared with the "ring" of the straight 90-10 alloy. It is a good plan to check Brinell hardness of aluminium bronze diecastings and to endeavour to maintain the hardness figure between 110 and 130.

Aluminium bronze is usually diecast by the gravity process and providing that attention is given to the non-turbulent flow of the metal in the mould excellent results

* *Jour. Inst. Metals*, 1922.

may be obtained and an accuracy of plus or minus 0·005 in. per in. can be kept. Holes greater than $\frac{3}{16}$ in. diameter can be cast providing that a taper of about 15 thou. per in. is allowed on the cores, but because of the high melting point and shrinkage of the alloy small holes of less than this diameter should not be attempted; for similar reasons it is unwise to consider the casting of threads or the inclusion of elaborate undercuts.

The die is generally made of an untreated low carbon steel, nickel steel, semi-steel or even cast iron. Cores are usually made of alloy steel and the life of a well made mould will be anything between 5,000 and 15,000 castings depending on the size and complexity of the job. Because of the combination of high casting temperature, brief freezing range and high contraction (the total shrinkage is 2%) the production of satisfactory and sound aluminium bronze diecastings requires special precautions to be taken; abrupt changes of direction and section should be avoided, usually the section of such a diecasting should not be less than $\frac{3}{32}$ in. while if it is more than $\frac{1}{2}$ in. the complete elimination of contraction cavities becomes most difficult.

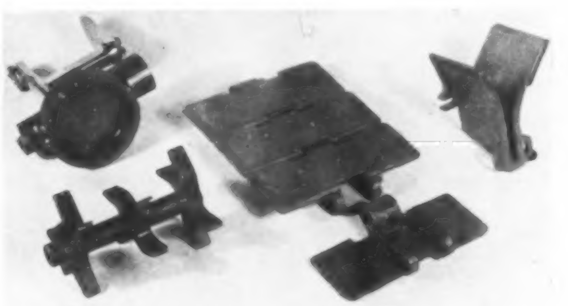


Fig. 2.—Aluminium-bronze die-castings for application to the dairy industry.

The group of gravity diecastings represented in Fig. 1, illustrate the wide field of application of these productions; the photograph shows a motor car spring shackle, a cup used in bottle washing machinery, a half bearing for a concrete mixer, a control gear component as used on the London Underground Railway, a bevel wheel used on printing presses and the over-hanging arm of a microscope. Fig. 2, illustrates some special applications to the manufacture of foodstuffs and to the Dairy industry. One of the chief consumers of aluminium bronze diecastings is the motor trade; nearly all the gear boxes in British automobiles contain gravity diecast selector forks; other uses are bumper fittings, steering gear components, windscreen pillars, door handles, starting handle bearings and steering wheel centres.

Although the appearance of the alloy in the polished condition is most attractive, the usual finishing processes can be applied without difficulty. The alloy can be chromium-plated and a finish which is popular in this country is antique bronze which can be produced either by chemical means or by heat-tinting.

Quite often iron is added to the alloy in order to decrease grain size and improve tensile strength while additions of manganese and nickel are sometimes made. Of course, in such cases, the basis of composition must be adjusted with the inclusion of the third element, so that the formation of the brittle constituents is prevented; thus an alloy with iron 1·5%, aluminium 9%, balance copper is approximately the same structurally as the straight 90-10 alloy. There are wide possibilities for the improvement of these diecasting alloys by heat-treatment; the tensile properties of the alloy both with and without additions of other elements can be augmented by heat-treatment and also the aluminium bronze can be softened with little difficulty in order to facilitate machining operations.

Surface Hardening by Inductive Heat

UNTIL the development and perfection of the electric induction method of heating steel previous to hardening by quenching and tempering, there were several methods of surface hardening steel including carburising, cyaniding, nitriding, "Chapmanising," and the use of the acetylene torch. The object of all these methods, except the last, is to produce a hard surface on a soft, tough core and involve the absorption of other elements into the surface to be hardened—a process of diffusion in solid metal—and in all of them time is an important factor, and in some of them distortion as well as scaling, a disadvantage. In a large plant in the U.S.A., the bearing surfaces of steel crankshafts and other parts are now being satisfactorily hardened in from 1·8 to 6 secs., depending on the steel treated and the bearing size, and is being accomplished on practically a mass production scale. This new process, which has been named the "Tocco" process, is described by E. F. Cone* in a recent issue of *Metals and Alloys*.

Developments in all types of oil engines with augmented bearing pressures and speeds and the advent also of the newer and harder bearing alloys,—copper-lead, cadmium-silver, and cadmium-nickel—have necessitated crankshafts which will withstand severer operating conditions, as the harder bearings have an extremely wearing effect on crankshafts hardened by ordinary methods. The demand therefore, for crankshafts capable of operating many thousand miles without bearing failure or bearing adjustments has resulted in the development and use of inductive electric heat, carefully and automatically controlled for hardening surfaces.

In the "Tocco" process, a high-frequency current of 2,000 cycles is passed through an inductor block which surrounds, but does not touch, the bearing to be hardened. A very strong magnetic field is produced by this current which cuts the bearing surface through a small air gap and induces eddy currents in the bearing surface. This field also creates hysteresis losses in the bearing surface and heat is generated in the surface by the combined eddy currents and hysteresis losses while the inductor block remains comparatively cool. The surface of the steel is not overheated, as due to the inherent reaction of the steel as its temperature rises, the heating effect decreases as the critical point of the steel is approached. By pressure spraying through orifices on the inner surface of the block, instantaneous quenching results.

A wide range of steels both alloy and carbon, are being successfully hardened by the treatment. Such steels are first heat-treated in order to obtain a uniform grain size and a predominately sorbitic structure, in order to obtain a good bond between the case and core as well as to assure successful hardening. Shafts are machined to the point of final grinding, subjected to the hardening process, tempered at low temperature and then finished ground. During the process the bearing surface is heated to the quenching temperature for a depth of approximately $\frac{1}{8}$ in., and the degree of hardness obtained is about 60 Rockwell C or approximately 85 Scleroscope or 600 Brinell, and this high hardness is maintained through about 80% of the depth of the hardened area. The original structure in the fillets of the shaft is not changed nor is the core affected and this is important as stress concentration is decreased and not increased.

This hardening process is also applicable to other than cylindrical shapes. Camshafts are now being hardened by the process on a large production scale, and it can also be applied to axle shafts and similar products with the rollers riding directly on the shaft.

The Head Office and Showrooms of Cambridge Instrument Co. Ltd., are now at 13, Grosvenor Place, London, S.W.1.

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* *Metals and Alloys*, 1938, Vol. 9, No. 1, pp. 1-6.

The Institute of Metals

Thirtieth Annual General Meeting

Further progress in the activities of this Institute was indicated at the recent Annual General Meeting, held in London. This has been encouraged by another increase in membership, and the enthusiasm displayed at this meeting must have been especially gratifying to the Council. Below is a brief summary of the meeting.

VARIATIONS of the procedure of the past 30 years were made by the Council of the Institute of Metals in connection with the recent Annual General Meeting held in London. By the new arrangement "official business" was divorced from the reading and discussion of papers. Contrary to custom, the meeting began in the evening of March 8, with the presentation of the annual report of the Council, the election of the Council for 1938-39, and the delivery of his inaugural address by the new president. The morning and afternnon sessions of the following day were devoted to the presentation and discussion of eight papers, and the closing day of the meeting also was divided into two sessions—the morning being devoted to a general discussion on "The Training and Employment of Metallurgists," which was opened by Professor R. S. Hutton, of Cambridge; while a series of visits to works of metallurgical and engineering interest concluded the meeting.

Report of Council

The President, Mr. W. R. Barclay, O.B.E., was in the chair at the opening of the proceedings when the report was submitted. Exceptional activity and considerable progress in many directions was experienced during 1937. Many new schemes for increasing the Institute's usefulness to its members have been put into operation, while others are under consideration with a view to their becoming effective in the immediate future.

The President announced that the Council of the Institute of Metals had accepted an invitation from the Council of the Iron and Steel Institute to share office and other accommodation at 4, Grosvenor Gardens, London, S.W. 1. This fine and conveniently-situated building (formerly the American Embassy) has been leased by the Iron and Steel Institute, and adequate accommodation for the Institute of Metals is provided as from June, 24, 1938. Both Institutes will retain their identity and staffs, but there would be a joint library and reading-room, while certain committee rooms would be in common.

Other outstanding features of the year's activities to which more detailed reference is made later are: An invitation from our American friends to hold the 1938 Autumn Meeting in the United States of America in conjunction with the Iron and Steel Institute; the offer (gratefully accepted by the Council) of a platinum medal to be awarded for outstanding services to the industry; and an internal reorganisation and strengthening of the staff of the Institute, which it is believed will lead to greater efficiency.

Sir William Bragg, O.M., K.B.E., M.A., D.Sc., F.R.S., and Professor Dr. C. A. F. Benedicks were appointed honorary members of the Institute. The Council also nominated Dr. H. Moore, C.B.E. (Past President), and Mr. W. Murray Morrison (sometime Vice-President) as Fellows of the Institute.

First Award of the Institute of Metals Medal

Many members of the Institute have felt for some time the need for a means whereby acknowledgment could be made of outstanding services rendered to the industry on both the scientific and technical side. By the generosity of the Mond Nickel Company this abstract idea has been made concrete, and the Council is now in a position to present a medal in the precious metal—platinum, either each year or at longer intervals as may be decided by the Council. The medal, which has been designed by a well-known artist, Mr. Harold Stabler, is shown in the accompanying illustrations.

The Council unanimously chose Sir William Bragg as the first recipient of this award, and in making the presentation the President referred to Sir William's brilliantly-conceived application of X-rays to the study of the structure

These illustrations show obverse and reverse sides of the new Institute of Metals' Medal presented to Sir William Bragg (approx. actual size).

of matter which has influenced scientific research far beyond the boundaries of the particular branch of applied science represented by this Institute, and has brought to him many and well-deserved honours from universities and scientific bodies throughout the world. Turning to Sir William, he said: "We feel a great pleasure to-night in being able to add to the many tributes that have already been paid to you this particular recognition of the value of your work to investigations of the structure of metals. Through your work and that of your gifted son, there has been placed at the service of scientific research workers in our field an entirely new technique, the value and potentialities of which we are only just beginning to realise. We are glad indeed to have the privilege to-night of thanking you in the form of the first award of the 'Institute of Metals Medal.'

"I am sure that I am correctly interpreting the feelings of both the Council itself and our members generally, in saying that we have also a very personal pleasure in presenting this medal to you, for, in addition to your scientific services, you have for many years evinced a very kindly and greatly-appreciated interest in our Institute and its proceedings. We have been glad on many occasions

to welcome you at our gatherings, and we esteem it an honour to have you on our very short and distinguished list of honorary members. We have also had the pleasure of including you in our long list of May Lecturers, and through these and other channels we have come to regard you as one of ourselves, and in handing this medal to you, I hope you will permit me to emphasise this aspect of our feelings towards you, and to assure you not only of our highest esteem, but of our warm personal regards."

Election of Officers

The election of the following officers for the year 1938-39 was announced: President, C. H. Desch, D.Sc., F.R.S.; Vice-President, Professor J. H. Andrew, D.Sc.; Members of Council, Dr. J. W. Donaldson, Eng. Vice-Admiral Sir George Preece, K.C.B., and Mr. H. S. Tasker, B.A. The election of 118 new members was also reported.

Induction of the New President

Dr. Desch is so well known that it is unnecessary to attempt any account of his career. He is an original member of the Institute of Metals, and contributed to the proceedings at the first provincial meeting held in Birmingham nearly 30 years ago, and has served on its Council continuously for 10 years, for the last five of which he has been Vice-President. Mr. Barclay expressed himself as particularly happy to induct Dr. Desch as President, as, in addition to possessing scientific ability of the highest order, he has those great qualities of human sympathy and sincerity which are essential to leadership in every sphere. Dr. Desch occupied the chair, and suitably responded, and subsequently delivered his Presidential Address on:

A Chemist's View of Metallurgy

In thanking members for the great honour conferred upon him in being elected President, Dr. Desch expressed himself as fortunate in taking office at a time when there is every prospect with the marked expansion of industry of entering upon a period of advance. Systematic planning of industry is still in a very imperfect stage, but that it may be possible at all there must exist a mass of accurate and ordered information, technical as well as economic. Such an Institute as this, which makes possible the full and frank exchange of technical knowledge, is helping in that direction, not only by its collection of facts, but also by fostering a spirit of co-operation in the industry.

The President referred to the types of papers presented, the greater number being from research laboratories, while those engaged in technical operations hesitate to offer the Institute matter which would, if suitably presented, arouse great interest. Papers having a direct practical bearing would be welcomed, and, if necessary, assistance given in putting material in a suitable form. A third type of paper was suggested. The work summed up in the form of an equilibrium diagram, especially if established by means of X-rays, is often understood only with difficulty by those technical metallurgists to whom the information implicit in the diagrams would have practical value. The need for using the simplest language consistent with accuracy was emphasised.

Discussing the practical difficulties in the way of treating the subject of metallurgy as a whole, Dr. Desch stated that the separation between the ferrous and non-ferrous industries and between the industry of smelting and refining, on the one hand, and of alloying, casting, working, and finishing on the other, presents a real obstacle to unification, except on the educational side. There is, however, one department of metallurgy in which no such difficulty need arise. That is the study best known as metallography, which is concerned with the structure and properties of metals and alloys, making use of methods based on physics and on chemistry.

Within the last few years metallographic research has been transformed by the introduction of new physical methods of study. Chief among these is the determination of crystal structure by means of X-rays. The original discovery by Laue, so brilliantly applied and extended by Sir William Bragg and his son, has proved of incalculable value in metallurgical research, giving a new insight into the internal structure of solids, assisting greatly in the study of changes during cold-working, recrystallisation, age-hardening and other processes, and furnishing a rapid and accurate method of determining phase equilibria in systems of alloys. The physicists, having been brought into contact with metals in this way, have found that metallic structures lend themselves well to theoretical treatment. To-day, metallographic research tends more and more to become an application of physics to the special case of metals; but, as Dr. Desch came to metallurgy by way of chemistry, this fact led him to dwell on the chemical approach to metallurgical problems, without seeking in the least to undervalue the help that is given by physics.

In the first place, he reminded us that the oldest metallographic method, that of microscopical examination, is essentially chemical, since far greater use is made of etched specimens than those that are unetched. The subject of etching has scarcely received all the attention it deserves. Etching reagents are chosen mainly for the contrast which they give, so that the best photographs may be obtained, and only rarely for their specific reactions. Mention was also made of the importance of chemical analysis for metallurgical research. As a means of control of industrial processes, it is the oldest and still the most generally applied. Analytical laboratories were introduced into metallurgical works before any use was made of the microscope or of physical measurements. Even now, establishments which have no other scientific control may employ a works chemist, even though he be confined to the simplest of routine analyses, but analytical methods in the more highly developed industries are undergoing a profound change. With the increased use of highly-purified metals—aluminium, copper, zinc, lead and cadmium are all obtainable in commerce with a purity of 99·99%, or better—interest is being taken in the estimation of very minute amounts of foreign elements.

The chemical aspects of metallography, however, is only one of the applications of chemistry to metallurgy. Apart altogether from the extraction of metals from these ores, many industrial processes are essentially chemical. Electro-deposition is one such, while refining by means of slags or vapours, pickling and bright annealing are others. So, too, the whole field of corrosion, whether by the atmosphere, by liquids, or by heated gases, belongs mainly to the chemist. There is no likelihood that the connection between chemistry and metallurgy will become less, however increasingly the scientific study of metals may seem to be based on physics, or however great the development of industrial plant on the engineering side.

TECHNICAL SESSIONS

The technical sessions were well attended, and considerable discussion took place following the introduction of the majority of the papers. Below is given a brief summary of the papers presented.

The Nickel-Copper-Magnesium Alloys

The effect of nickel on some magnesium-rich copper-magnesium alloys is dealt with in a pap r by Professor W. R. D. Jones and Mr. K. J. B. Wolfe. The alloys upon which this work was carried out have been described in the *Journal of the Institute of Metals*.[1] The results of experiments show that the improved mechanical properties given to magnesium when in the "as cast" condition by small additions up to about 2% copper are enhanced by the addition of nickel, if the combined alloy content be 2¼ to 2½%. A nickel content of 0·5 to 1% (in the combined alloy content) has a greater effect than a corresponding copper content. A useful result due to the addition of nickel is that the values for reduction of area are generally higher than the corresponding values for the elongation. These alloys are readily forged or rolled, and, provided

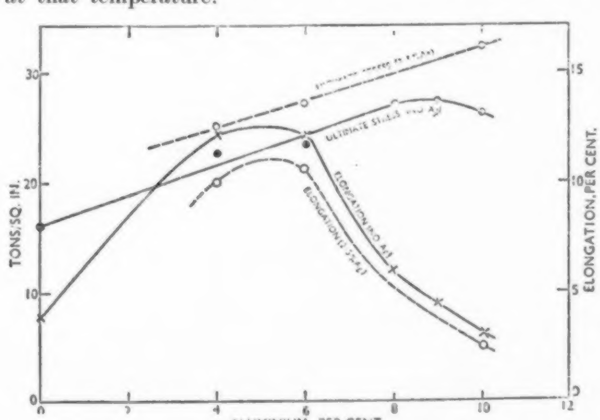
1 W. T. Cook and W. R. D. Jones, *J. Inst. Metals*, 1926, **36**, 157.
W. T. Cook and W. R. D. Jones, *J. Inst. Metals*, 1927, **38**, 103.
W. R. D. Jones, *J. Inst. Metals*, 1928, **40**, 85.
W. R. D. Jones, *J. Inst. Metals*, 1931, **46**, 395.

that care is taken to prevent cold-work, reasonably good ductility values are obtained. In the case of forged and/or rolled alloys, the beneficial effect of the addition of nickel as well as copper to magnesium is not so pronounced; the effect of nickel depends to some extent on the proportion of copper. In the case of forged bars, the best results are given by an addition of 0·5% nickel to 1% copper, but if the billet is rolled after a preliminary drawing down under the hammer the copper should be increased to 2% to give the best values for the mechanical properties. Billets which have been rolled after a preliminary drawing down, give better mechanical properties than those which have been drawn down to the same size.

Alloys of Magnesium. Part VII.

This paper, by Dr. J. L. Haughton and Mr. A. E. L. Tate, deals with the mechanical properties of some wrought aluminium-magnesium and silver-aluminium-magnesium alloys. It describes part of the investigation of the constitution and mechanical properties of magnesium alloys which is being conducted at the National Physical Laboratory, under the direction of Dr. C. H. Desch, F.R.S., for the Metallurgy Research Board of the Department of Scientific and Industrial Research.

In Part II of the research, the mechanical properties of some aluminium-magnesium alloys were studied, and preliminary work was also carried out on the effect of mechanical treatment. Later the effect of adding silver to aluminium-magnesium alloys was studied, and the results were published in a monograph entitled: "Magnesium and Its Alloys."[2] It was found that the addition of 2 to 3% of silver to an alloy containing about 8% aluminium gives alloys which, in the heat-treated condition, have an ultimate stress of 25 tons/in.^{2}, a proof stress of 17 tons/in.^{2}, and an elongation of 4%; that the addition of calcium improves the ultimate stress of magnesium at moderate temperatures (about 200° C.); and that cerium has a marked effect in increasing the strength of magnesium at high temperatures (300° C.), while the addition of cobalt leads to still further increase. Thus, an alloy containing cerium 10, cobalt 1·5, and manganese 1·5% has an ultimate stress of 7·4 tons/in.^{2} at 300° C., as compared with one of less than 5 tons/in.^{2} for a 9% aluminium-magnesium alloy at that temperature.



Mechanical properties of aluminium-magnesium alloys (with and without 2.5% silver) after 60% reduction at 200°C

These investigations, however, were rather in the nature of preliminary surveys, and the present paper deals with a more complete investigation of both series of alloys. It is divided into three sections, dealing respectively with: (1) aluminium-magnesium alloys; (2) silver-magnesium alloys; and (3) the effect of different amounts of work on the hardness of both the binary and the ternary alloys, and the effect of the temperature at which deformation is carried out on the mechanical properties of these alloys.

The authors investigated the mechanical properties of pressed magnesium alloys containing up to 10% aluminium, and studied the effect of adding up to 4% silver. A maximum in the mechanical properties at about 9% aluminium which was suggested by earlier work, at the National Physical Laboratory and elsewhere, is shown not to exist, while little if any benefit, either in the aged or annealed state, is obtained at room temperature by the addition of silver to alloys which have been forged at 380° C.

The effect of varying the amount of reduction given to a forging has been studied, and it is shown that the work penetrates to the centre of a 3½-in. diameter ingot after a reduction of 40 to 50% has been given, and that no further hardening is obtained until a reduction of 90% is reached, when a definite increase of hardness takes place.

Forging alloys at a temperature of 200° C. (after a preliminary breaking down at 380° C.) causes an appreciable increase in the ultimate stress without much loss of ductility, as compared with alloys which have been forged at 380° C. The tensile strength of alloys treated in this way is still further increased by the addition of silver. An alloy containing 8·5% aluminium and 4·2% silver has a tensile strength of over 30 tons/in.^{2} with an elongation of 5%; an alloy containing 6·5% aluminium and 1·5% silver has an ultimate stress of over 27 tons/in.^{2} and an elongation of 11·5%, and one containing about 4% aluminium and 1·5% silver has an ultimate stress and elongation of 24 tons/in.^{2} and 13·4%, respectively. The second of these alloys has a proof stress of 21·3 tons/in.^{2}. These values compared very favourably with those for a specimen of "R R 56" alloy in various conditions of forging and heat-treatment.

Sintered Alloys. Part I.

This paper by Mr. G. H. S. Price, Dr. C. J. Smithells, and Mr. S. V. Williams, describes an investigation of the preparation of alloys by sintering mixed metal powders at temperatures at which a small quantity of a liquid phase is present. So far as the authors know, no previous investigation has been carried out under these conditions. The investigation has mainly been confined to mixtures of tungsten with small amounts of copper and nickel, although certain conclusions regarding the mechanism of the sintering process have been checked by making up alloys of other metals.

The effect of time and temperature of sintering has been investigated with a copper 2, nickel 5, and tungsten 93% alloy. Alloy formation, determined by density measurements and micro-examination, does not progress uniformly as the sintering temperature is increased, but shows a rapid increase at a temperature of about 1,300° C. Although considerable solid diffusion may occur at lower temperatures, it is essential that this temperature should be exceeded if alloys of "theoretical" density are to be obtained.

The time for which the alloys must be held at the sintering temperature to reach equilibrium is largely dependent on the composition. An alloy having a high percentage of the liquid phase reaches its "theoretical" density sooner than one in which the amount of liquid phase present is small.

The effect of composition has been investigated for a series of alloys containing from 80 to 97% tungsten. With copper only, the tungsten particles are merely wetted and cemented together; there is no grain-growth and much porosity. With nickel only, the full density is obtained after sintering above 1,500° C. When both copper and nickel are present, two factors are important: the ratio of nickel to copper, and the total percentage of these metals. Maximum density is obtained when the nickel-copper ratio is about 2 : 1, and the tungsten content lies between 89 and 93%.

A fourth fundamental variable is the fineness of the metal powders, a longer time, or a higher temperature, being required for complete sintering when the tungsten grains are coarse. Fully-sintered alloys prepared in this way have no porosity, densities equal to the "theoretical" values, and a tensile strength up to 40 tons/in.^{2}. Micro-examination reveals the presence of large, rounded tungsten grains, whose diameter is about 100 times that of the original

[2] J. L. Haughton and W. E. Prytherch, "Magnesium and Its Alloys," London, 1937.

particles, embedded in a continuous matrix of copper-nickel phase saturated with tungsten.

An explanation of the changes which take place during sintering, based on the abnormal solubility of particles less than 1μ in diameter, accounts satisfactorily for all the observations. This hypothesis has been confirmed by results obtained with sintered silver-copper and copper-iron alloys.

The Creep of Tin and Tin Alloys. Part II.

In a previous investigation dealing with the creep of tin containing additions of silver, bismuth, antimony, or cadmium, Professor D. Hanson, and Mr. E. J. Sandford found that antimony or cadmium conferred the greatest beneficial effects, and this paper by the same workers describes an investigation on the influence of additions of these two elements together. It is shown that cadmium and antimony added together to tin produces alloys which have creep properties superior to those of any other tin alloys previously studied ; the exact composition required depends on the heat-treatment. It has been found, for instance, that alloys which are cold-rolled and alloyed to self-anneal at room temperature require 7% cadmium and 9% antimony for the best properties. A life of 724 days at a stress of 1,600 lb./in.^{2} is found, thus, this alloy could be stressed in practice in the neighbourhood of 1,200 to 1,400 lb./in.^{2} without failure occurring for many years. This is a marked improvement on pure tin, the safe stress for which is not more than 150 lb./in.^{2}

The influence of annealing at 170° and at 200° C. is discussed. After annealing at 170° C., the most beneficial composition is 2% cadmium and 7% antimony ; a safe stress for this alloy is 3,700 lb./in.^{2} The authors show that grain size is an important factor in determining creep-resistance, and, as the tensile strength is not greatly influenced by grain-size, no relationship is found between these two properties in the annealed alloys investigated.

The effect of additions of 1 and 2% silver, 1% copper, or 0·3% nickel is discussed. The silver and copper alloys show similar creep properties, but the nickel alloy is inferior. An alloy containing 1% cadmium and 3·5% silver has great creep-resistance when cold-rolled and self-annealed ; it is superior to the alloy containing 7% cadmium and 9% antimony.

The Physical and Mechanical Properties of Nickel-Brasses

A very wide variety of copper-rich non-ferrous alloys containing nickel are now manufactured and used, the two chief and most important groups being the straight copper-nickel alloys commonly known as cupro-nickels and the ternary alloys with copper and zinc, known as nickel silvers or German silvers. The latter group covers a very wide range of compositions, with a nickel content of about 5 to 30%, and with zinc tanging from about 5 to 30%. These alloys may be subdivided into three principal groups —viz., cold-working, hot-working, and casting alloys. Those that may be regarded as cold-working alloys generally contain from about 10%, or rather less, to 30% nickel, and about 10 to 30% zinc. Structurally, these alloys resemble 70 : 30 brass, in consisting of a single solid solution. Although they are commonly fabricated cold, there is, of course, no hard-and-fast line of demarcation between so-called cold-working and hot-working alloys, and many of the alloys in this range can, for example, under suitable conditions, be hot-rolled. Those regarded as essentially hot-working alloys contain about 38 to 45% zinc, and from about 6 to 16% nickel. Structurally, they consist of varying proportions of the α and β constituents. As in the case of the brasses, the β-phase is more easily worked hot than cold, and the rough classification into hot- and cold-working alloys, according to the presence or absence of the β-phase, is similar to that commonly used for brasses. The casting alloys vary considerably in composition, and very commonly contain appreciable additions of lead and tin.

The characteristic hot-working alloys with a duplex structure, a relatively high zinc content, and low or medium nickel content, are often known as nickel-brasses, and in fact, they may be regarded as α-β brasses containing nickel additions. A typical alloy of this type is that containing 10% nickel and 45% of copper and zinc. Comparatively little detailed information has been published regarding these alloys, and the work which forms the subject of this paper by Dr. Maurice Cook, was carried out in order to obtain further information regarding the hot-working, physical, and mechanical properties of alloys of this type. The first part of the work, namely, that on chill-castings and forgings, was of an exploratory character, to obtain an indication of the range of composition likely to provide alloys which may be of practical interest.

Observations, including the determination of machinability values and hot-stamping properties, have been made on three alloys, in the form of extruded rod, with a copper content of 45% and nickel contents of 10, 12½ and 15%, and on the 10% alloy, with and without the use of cupro-manganese as deoxidant, and with additions of lead, phosphorus, and silicon. The differences in physical properties of these three alloys of varying nickel content were not very marked, but the alloy containing 10% nickel gave superior machinability values, and, moreover, gave satisfactory results in the hot-stamping tests over the range of 600° to 850° C. ; the other two alloys compared very unfavourably with it in this respect.

The addition of lead to the 10% nickel alloy improves the machinability, but adversely affect its hot-stamping properties, and it also tends to reduce the tensile strength and elongation values.

A Study of Some of the Factors Controlling the Porosity of Hot-Tinned Coatings on Copper

In this paper by Dr. W. D. Jones, a distinction is drawn between the surface conditions of a tin bath (in which copper is being tinned) at the entry of the copper, and at the exit. Molten salts and other materials maintained on the bath at entry are termed *fluxes*, and control the wetting of the copper surface by the tin ; and such materials at the exit from the bath are included in the term *cover*, and control the stability of the molten tin film on the copper surface after it has left the bath.

A major source of porosity in tin coatings on copper is due to a " running off " or " globularizing " of the molten tin film. This phenomenon is termed *dewetting*, and is indicative of an instability in the molten-tin film caused mainly by a high tin surface tension. Certain covers such as palm oil, stannic bromide, oxide films, etc., by reducing surface tension decrease the tendency to dewet. Other covers, such as ammonium chloride, or resin, permitting of a high surface tension, increase the tendency to dewet. Dewetting is favoured by the presence of suitable nuclei, of which the most important are scratches and other discontinuities of the copper surface, imperfectly wetted areas, inclusions, and local variations in surface tension caused by temperature and concentration variations. The extent of dewetting is reduced by increasing the viscosity of the tin film (by presence of intermetallic compounds and by low temperatures), or by rapid solidification.

Some conclusions of an important practical nature are concluded from this study. In order to obtain coatings of a minimum porosity, the following points should receive attention : (*i*) the copper base should be thoroughly degreased and adequately fluxed; (*ii*) a cover which reduces the surface tension of the tin bath is desirable, although satisfactory coatings using only an oxide film can be procured (with some deterioration in the appearance). The use of ammonium chloride alone should be avoided. (*iii*) Precautions should be taken to prevent the formation of dewetting nuclei. General roughness and scratches are the most important types of nuclei. It is not possible to stress too much the necessity of a highly-polished surface if all dewetting is to be avoided. Inclusions in the copper base also act as nuclei, an explanation of the difficulty in

(*Continued on page 204*)

Modern Electric Furnaces for the Aluminium and Light Metal Industries

By G. C. CASTLE

The characteristic qualities of aluminium alloys depend largely upon the treatment to which they are subjected during their manufacture. Melting temperatures, for instance, must be under careful control, and in this article the use of electric furnaces is discussed.

DURING the last 25 years rapid progress has been made in the use of electric furnaces. Electric furnaces can be readily controlled to give the exact temperatures required, and it is possible to control the atmosphere in them so that the metal is not contaminated.

Types of Electric Furnaces

Modern electric furnaces are of three main types. In the first, and perhaps the most widely used, the metal is heated either by means of a resistance, consisting of such materials as carbon or nickel chrome ; while in some instances, the metal itself forms part of an electric circuit, and the resistance it offers to the passage of the current raises the temperature to the required degrees. In the second type of furnace an electric arc produces the heat required. The third type is the induction furnace. In this latter furnace a coil of wire surrounds the furnace chamber, and is connected to a supply of alternating electric current at high frequency. The charge of metal to be treated is placed inside the chamber, and when current is passed through the coil a secondary current of low voltage, but extremely high amperage, is induced to the charge. This has the effect of raising the temperature of the metal.

Until recent years the induction furnace, shown in Fig. 1, was used chiefly for the melting of copper alloys. Great progress has recently been made in the design of these furnaces, and they are now used for dealing with many other metals and their alloys.

The rapid development in the production and working of aluminium and its alloys has entailed a corresponding development of suitable types of furnaces capable of melting the material with maximum economy and a high standard of quality.

It is important that the melting process should be attended by the least possible amount of loss by oxidation, and that the cast product should be as free as possible from gas inclusions and impurities. A further aspect to be borne in mind in connection with the choice of a furnace is that of the costs of maintenance and operation. Among the types of furnaces applicable to light metals, electric furnaces are widely adopted, from the smallest crucible type to the largest resistance or induction furnace.

The manufacture of high-grade aluminium alloys is dependent only in part on the management of the furnace, and is governed to an important extent by the construction and method of heating the latter. Three main conditions have to be fulfilled :

(1) Care must be exercised to prevent inclusions either of gas or of oxides.
(2) The final product must conform very accurately to the required chemical composition.
(3) When the material is heat-treated after being shaped, with a view to improving its quality, accuracy of temperature is necessary to obtain the specified mechanical properties.

In the melting of high-grade light metals care is necessary to ensure that minimum oxygen is absorbed from the atmosphere to form aluminium oxide, and also that the alloy is afforded no opportunity of taking up hydrogen, whether from the refractory lining or from the air. Further, the amount of any given constituent lost by burning must

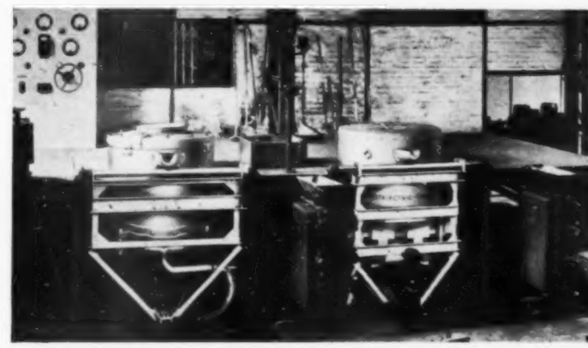


Fig. 1.—Two induction furnaces : a recent installation.

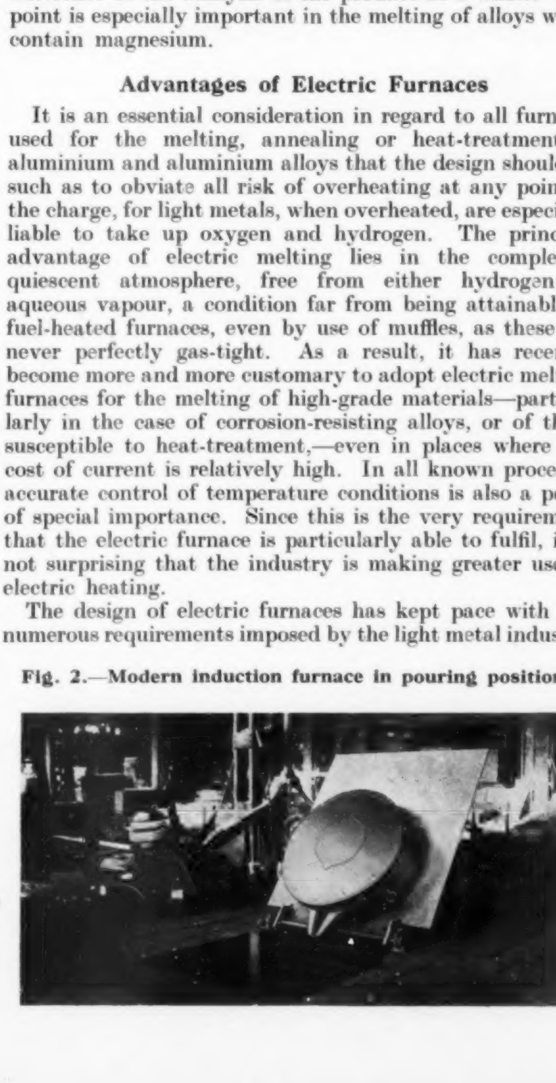
be limited to an amount so small as to make no appreciable difference to the analysis of the product as a whole. This point is especially important in the melting of alloys which contain magnesium.

Advantages of Electric Furnaces

It is an essential consideration in regard to all furnaces used for the melting, annealing or heat-treatment of aluminium and aluminium alloys that the design should be such as to obviate all risk of overheating at any point in the charge, for light metals, when overheated, are especially liable to take up oxygen and hydrogen. The principal advantage of electric melting lies in the completely quiescent atmosphere, free from either hydrogen or aqueous vapour, a condition far from being attainable in fuel-heated furnaces, even by use of muffles, as these are never perfectly gas-tight. As a result, it has recently become more and more customary to adopt electric melting furnaces for the melting of high-grade materials—particularly in the case of corrosion-resisting alloys, or of those susceptible to heat-treatment,—even in places where the cost of current is relatively high. In all known processes accurate control of temperature conditions is also a point of special importance. Since this is the very requirement that the electric furnace is particularly able to fulfil, it is not surprising that the industry is making greater use of electric heating.

The design of electric furnaces has kept pace with the numerous requirements imposed by the light metal industry

Fig. 2.—Modern induction furnace in pouring position.



in its impetuous course of development, and in addition to melting furnaces a considerable range of different types of heat-treatment furnaces is available in which resistance heating predominates.

The range includes portable furnaces for general heat-treatment up to 1,000° C.; furnaces for the bright annealing of non-ferrous materials; continuous-belt-conveyer furnaces for the continuous heating of various parts, either in connection with water or oil quenching, or, alternatively, for annealing; industrial ovens for enamelled stoving; pot furnaces, for the melting and holding of salts for heat-treatment, or, alternatively, for the holding and melting of lead, aluminium and other light metal alloys having a temperature not exceeding 850° C.; car and pusher type furnaces, for heat-treating billets, forgings, stampings, tubes, etc.; tempering furnaces, with recirculating fan for low-tempering annealing, etc.

Although many types of furnaces are used for both melting and heat-treating aluminium alloys using various heating media, the special advantages offered by the use of electricity in properly designed furnaces has greatly increased the use of this form of heat in recent years.

Planned Publicity for Engineering Products

A complete outline of the considerations which should be included in framing any sales promotion scheme for engineering products was given by Mr. L. Rowlinson, in a recent paper before the Manchester Association of Engineers; he discussed many details of value to engineers and manufacturers, brief reference to some of which will be of interest.

IT is necessary to distinguish between the marketing of engineering products, made by technical men and bought by technically-minded men for some specialised technical purpose, and of general products bought by the non-technical buyer. The former class, which is covered by this title, is sold to the technical user after critical examination of his need for it, of its design and materials of construction, of what it will do, and of what it will save or earn, on a monetary basis. General products, on the other hand, are often sold on an emotional appeal. The manufacturer of specific plant or appliances needs to study the specialised requirements of manufacturers or processors of many commodities and may find that there are possible uses for his product of which he had been ignorant but which could be exploited to considerable advantage. Thus, the technical plant manufacturer needs an understanding of general marketing principles and a thorough knowledge of the needs of the several specialised industries to which his product may be applied.

The three basic stages of planning sales promotion upon which a logical plan can be built, are: study of the market; study of the product; and study of the customers' individual requirements. A clearly defined sales policy is essential, but this cannot be defined until the manufacturer has full information about both product and market. A point which deserves emphasis is that in which the manufacturer is urged to investigate his product from the sales promotion aspect, for which purpose nine questions are outlined which form a logical skeleton for acquiring this vital information regarding the product. In addition valuable information can be gained from questioning the outside sales staff.

Dealing with investigation of the market, Mr. Rowlinson examined and discussed such vital questions as: What industries use the product? What firms are engaged in these industries? What is the trade demand for the product? How does the product reach the market? Do all industries use the product in the same way? Are you receiving your fair share of existing business? What are your competitors doing? Whether there exist, or are likely to develop, new outlets, or a demand for products you should, but at present do not make? and: Can advantage be taken of any tendency towards a change in the nature of the demand due to developments taking place in the customer's own industry?

After consideration of these investigation factors, the manufacturer is recommended to make a detailed examination of sales and production figures with the object of determining the budgetary control of sales, the quantities to be put into production to meet estimated sales, the ascertaining of profitable lines to form the subject of special sales efforts, establishment of salesmen's quotas in those cases where the product is suitable for this form of control, and many other appropriate subjects which will probably suggest themselves. And so a market survey of great value will have been compiled.

Discussing the question of how much to allocate for publicity, Mr Rowlinson reviewed such bases as a proportion of the previous year's turnover or profit; the allocation of a fixed annual sum; or the arbitrary method of allotting what can be afforded as and when required; but bearing in mind that the purpose of engineering publicity is to spend money to earn sales, it is futile to be niggardly with this as the objective. Mr. Rowlinson gave facts and figures to explain the difference between "minimum coverage" and the point of "diminishing returns," then dealt with considerations of space and frequency for advertising in the trade papers, contending that it is better to take the largest spaces one can afford and as frequently as can be afforded, continuity being more valuable than mere size.

Regarding the assistance given to outside representatives by technical advertising and sales promotion, Mr. Rowlinson stressed the value upon turnover of a carefully planned sales campaign, stating that the value of the outside representative is, perhaps, doubled and his turnover increased by advertising and education by printed matter, although the final closure of the sale still remains the care of the representative, and that the expenditure on advertising and sales promotion of what is equivalent to the yearly salary and expenses of, perhaps, two or three salesmen, has repeatedly been found to double the effectiveness of a dozen outside men.

A sound example of planning was shown on a six-month basis, and valuable information given regarding overlapping campaigns, Mr. Rowlinson stating that it is often convenient to commence a second campaign for another product three months after the beginning of the first, and thereafter at three-monthly intervals, continuing along these lines so that at any one time there is always a campaign well advanced and one recently begun. In this way a selection of industries is gradually worked through and it may be determined to make a fresh attack from time to time upon an industry which has already been dealt with some time before . . . It must be remembered that results accrue sometimes months or years after the approach has been made, and that a steadily increasing business is the best test of the success of such sales promotion campaigns.

Finally, it is emphasised that such work should be placed in the hands of a competent member of the staff, or if this cannot be afforded, in the hands of specialised advertising agencies with a knowledge of the marketing of engineering products of the type discussed, although the ideal remains the employment of a full-time sales promotion or publicity manager. Some firms do employ such an executive and also collaborate with specialised advertising agencies in a manner comparable to that of the relations between a consulting engineer and his clients.

Manufacture of High-Strength Light Alloy Extrusions and Their Use in Aircraft—Part II.

By R. WORSDALE

In the previous article the author discussed the extrusion process, in this section the finishing operations are considered. Views on the possibilities and limitations of extruded sections, manufacturing tolerances and the application of extrusions to aircraft are discussed.*

THE speed at which extrusion is carried out is extremely important, as is the temperature at which the billets are heated prior to being placed in the container. These two factors affect both the surface finish and the mechanical properties of finished sections. Speeds of extrusion vary, depending on the alloy and the section concerned, 3 ft. per min. being an average. It will be appreciated that the cross-sectional area and maximum length of sections are governed by the size of the billet container and its length (apart from heat-treatment facilities).

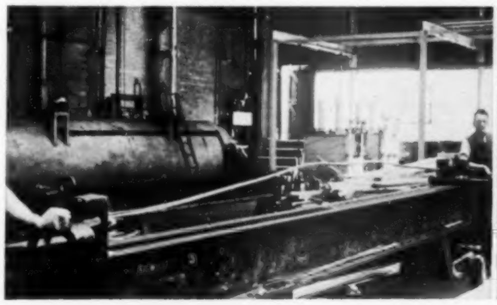


Fig. 15.—Stretching after solution heat-treatment (note distortion).

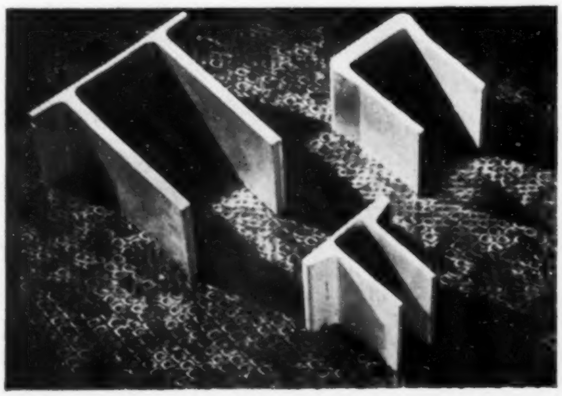
Fig. 16.—Special correction.

Finishing Operations

After extrusion sections have to be finished by heat-treatment, straightened, cut to length, and tested. When first extruded, they are perfectly true to contour and reasonably straight (Fig. 13). Heat-treatment, however, distorts them, sometimes very severely (Fig. 14). Straightening and correcting operations therefore are necessary in order to bring the sections within the tolerances laid down. Preliminary straightening is carried out on hydraulically-operated stretching machines. Sections are mounted in mechanically or pneumatically-operated jaws, one end of which is fixed, and the other is mounted on the head of an hydraulic cylinder (Fig. 15). The cylinder is so operated as to pull the section, thus removing the majority of kinks and bends. After stretching, those sections still needing it, are further corrected by hand, or on special correcting presses (Fig. 16). The stretching and correction must be very carefully carried out so as not to damage the sections and bring them below the permissible tolerances.

* Metallurgia, Vol. 17, No. 100.

Fig. 17.—Extra deep channels.

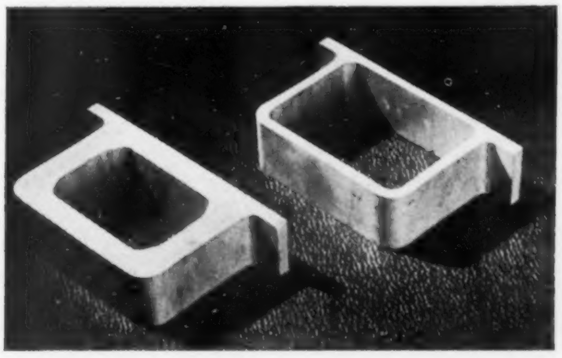


The Possibilities and Limitations of Extruded Sections

One great advantage which extruded sections have over rolled or drawn sections is that they need not be of constant thicknesses throughout. The mass of metal can be placed where it is most needed, and reduced at less important points. They can, too, be produced to reasonably fine limits, rendering machining operations unnecessary in many cases.

From the foregoing it will be obvious that it is difficult to define the limitations of manufacture and use of sections, since with greater experience in their production and the ever-exacting requirements of designers, sections are being produced to-day which were considered impossible two or three years ago. Examples at each end of the scale, such as T-sections 0·040 in. thick by 0·75 in. overall dimensions, weighing 1 oz. per ft., to those 1 in. thick by 6½ in. overall dimensions weighing nearly 20 lb. per ft., are common. Conventional types of sections—angles, tees, zeds and simple channels present no great difficulty; difficulties are encountered, however, in channels in which the ratio of depth to width exceeds one.

Fig. 18.—Tapered rectangular hollow sections.



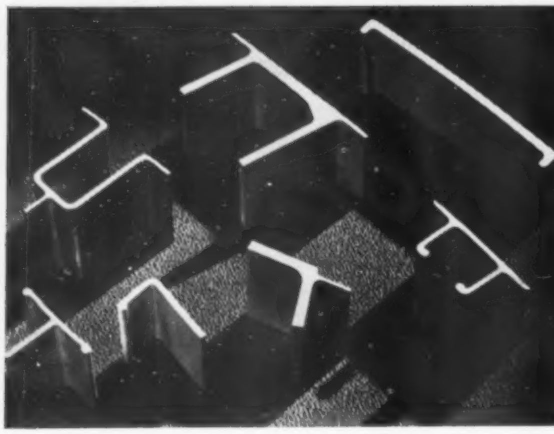


Fig. 19.—Sections with flanges and bulbs.

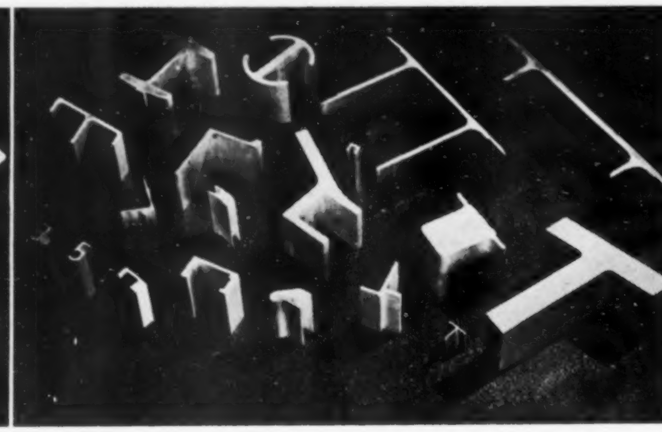


Fig. 20.—Collection of sections now being used on Aircraft.

Taking channels, such as are shown in Fig. 17, it will be noticed this ratio is exceeded, and in one case the sides are much thinner than the base. During extrusion of such sections the whole of the pressure of the tongue of the die is taken across one point, and that is at the top of the die where the sides end. It will, therefore, be readily appreciated that the deeper this tongue in the die the greater tendency there is for the die to be broken across that point. This tendency is overcome by making what is termed a solid die, that is the die plate and the die holder are made in one solid piece, or alternatively, the holder and bolster, so as to give greater support during extrusion, and to negative the tendency for the centre of the die to fracture.

Where a channel is very deep and narrow, it is impossible to extrude successfully to finished shape. In such cases, the extrusion is carried out with the webs splayed out, and subsequently drawn parallel after extrusion. This additional operation considerably enhances the cost, and can only be carried out on sections in which the thickness is reasonably constant all over, and of simple outlines.

It must be borne in mind, however, in designing any particular section that there is a definite ratio between the minimum thickness and the largest overall dimension. The cross-sectional area of any section, particularly in some of the more complicated, has a distinct bearing as to whether it is a practical proposition or otherwise. For instance, it is possible to produce a small T-section, having a thickness of ·040 in. and a maximum overall dimension of 1 in., but it is not possible to produce a section having the same thickness, but an overall dimension of, say, 3 in. This is due to the fact that a billet can only be reduced in area by a predetermined amount. In the case of small sections, it is the usual practice to overcome the small cross-sectional area of the section as extruded, compared with the cross-sectional area of the billet before extrusion, by the use of multiple hole dies, whereby anything from two to six sections are extruded at once. The sum total of the cross-sectional area of a multiple hole die in relation to the area of the billet, allows the section to be manufactured.

With a larger section, such as that just mentioned, owing to its large overall dimension, it is not possible to produce it in a multiple-hole die, and the reduction of area would be too great for a single-hold die; no matter what pressure, the extrusion simply would not take place. It is not possible to lay down any hard-and-fast rule which can be taken to govern the production of any section. Each has to be dealt with individually, but sufficient has been said to give a rough indication of the limitless possibilities which extrusion envisages.

Manufacturing Tolerances

Some designers have expressed surprise when told that certain sections they have called for require, what appear to them, wide manufacturing tolerances. Some detailed explanation is therefore necessary. Bearing in mind rigid temperature control at all stages of production, important factors governing tolerances are:

1. Contraction of metal after extrusion.
2. Straightening and correcting operation after heat-treatment.
3. Die wear.
4. Extrusion pressure.

1 and 3 are self-explanatory.

2.—Sections which are heat-treated and quenched distort in various ways, and have to be corrected by stretching,

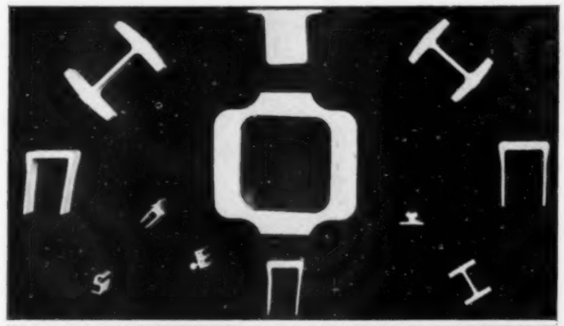
Fig. 21.—"Empire Boat" wing under construction, showing use of large tees.

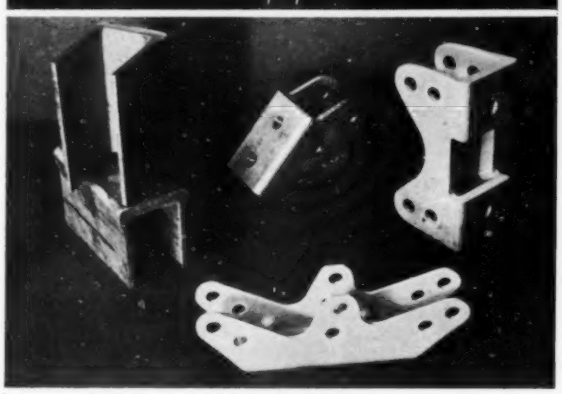
Fig. 22.—Plug attachment for bracing tubes.
Courtesy of Messrs. Short Brothers (Rochester and Bedford) Limited.

etc., as previously indicated—the amount of correction necessary depending on the degree of distortion—some distort so severely that special tools are necessary.

4.—Pressure on the die during extrusion materially affects the size of sections. For instance, sections extruded on two different presses through the same die will vary in size.

These and other factors have to be taken into consideration when fixing the limits to which any section, not conventional in shape, can be produced. Unless, therefore, a heavy scrap loss is to be faced, it can be taken quite





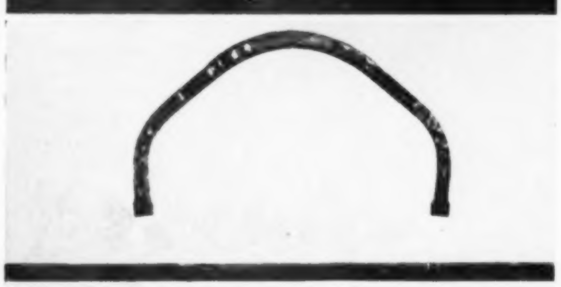


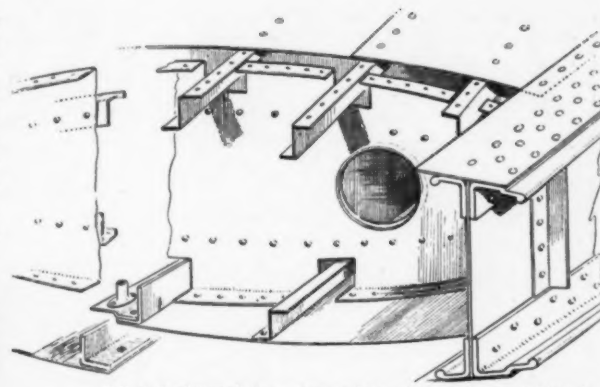
Fig. 23.—Collection of sections used on a modern Aircraft.
Fig. 24.—Showing channels used for brackets.
Fig. 25.—Hollow cantilever axle, (above—after machining and bending), (below—as delivered by Manufacturer).

definitely that the tolerances for which any manufacturer asks on sections are the closest to which he can normally be expected to work, bearing in mind the first cost of the section to the user, and obtaining reasonable speed of production in his own works.

Some sections can be drawn after extrusion to extremely fine tolerances, but unless such limits are absolutely essential, the additional cost involved, which is not inconsiderable, it is preferable to produce sections simply by extrusion, since the limits offered are close enough for all practical purposes.

Extrusion of Hollow Sections

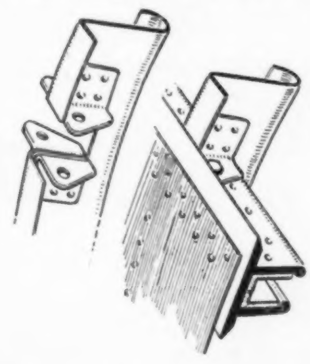
It is possible to produce hollow sections which can be conveniently described as irregular-shaped tubes. The chief point to bear in mind is that the hole must be central in



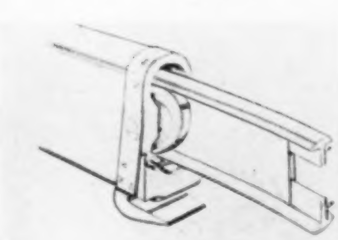
"Flight" photograph by courtesy of Fairey Aviation Company Limited.
Fig. 27.—Main wing spar and attachments on Fairey "Battle."

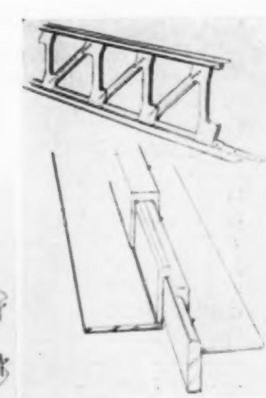
either axis of the section, since the mandril which has to be used in the production of hollow extrusions is located in the centre of the stem of the press, but is largely controlled by even pressure of the metal being extruded across each axis, to maintain it centrally. Such a section is shown in Fig. 18. Note the small flanges on the two bottom corners. Such small additions can be made to any hollow section, provided they do not upset the balance of the section from a manufacturing standpoint. The hole need not, of course, be rectangular—it can be any shape desired within reason—but not less than 1 in. in diameter, in strong alloys. This again is governed by the section required. Another point is that the walls need not be the same thickness throughout. Taking the section illustrated, the top and bottom walls can be one thickness, and the two sides another. Except under special circumstances, walls of varying thickness throughout cannot be made, as the section would be unbalanced, and the hole thrown out of centre. It is impossible to extrude consistently a hollow section with great eccentricity—although in all such extrusions eccentricity is present to a small extent.

Another and very important development which will considerably assist designers is the production of hollow extrusions in which the wall thickness tapers along its entire length. The two illustrations shown in Fig. 18



"Flight" photograph by courtesy of Fairey Aviation Company Limited.
Fig. 26.—Longeron attachment on Fairey "Battle."





By courtesy of Messrs. Handley Page Limited.

Fig. 29.—Application of extruded aluminium alloy section for wing spar flange construction.

Fig. 82. — Extruded sections employed in the construction of the track for Handley Page slots.

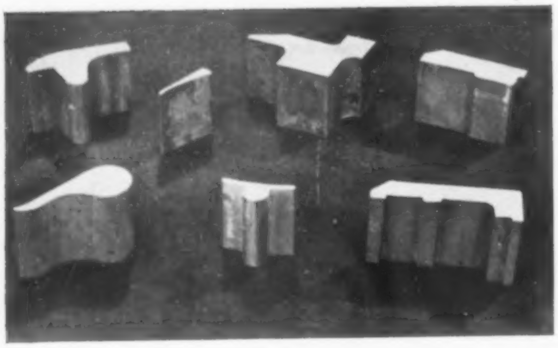


Fig. 30.—Sections showing how machining can be eliminated.

are cut from the same length. Such sections as these need not necessarily have a gradual straight taper from one end of the extrusion to the other, the taper can vary, and almost parallel portions introduced, the variation in thickness from one end to the other is almost limitless, also the section of hole can change throughout the length, for instance, from round to rectangular, and so on.

Tapered Solid Sections

Finally, after considerable experimentation, solid sections have been produced in which tapered portions have been extruded. A T-section can be produced with the head or flanges tapering in thickness along the entire length. Similarly, with angles and "Z" bars. This new development marks a considerable step forward in the production of strong alloy extruded sections, and is the answer to a demand which has been made for some time. It will save a tremendous amount of machining on the part of constructors and, by the elimination of joints, a considerable amount of weight. The process is, of course, patented.

Application of Extrusions to Aircraft

There are few parts of an aircraft in which extruded sections cannot be used, but it is difficult, due to constantly-changing design, to lay down any hard-and-fast rules. Main plane spars, longerons and fuselage formers, ribs, fin and tail plane members, sections for petrol tank ends and cabin tops, plug and other sections for bracing joints, door hinges and packing pieces are some of their present-day uses.

By a careful study of design several sections can be combined—a tee with a channel—so saving rivetting—thin flanges can be attached to large thick sections for skin and plate attachments. Stabilising bulbs, to prevent failure under compression, can be placed on tees, angles, etc., as shown in Fig. 19. Some indication of the variety of sections produced to-day for aircraft is given in Fig. 20.

A few examples of extruded sections on actual aircraft are illustrated. A wing of an "Empire Boat" under construction is shown in Fig. 21. Large tees, approximately 5 in. × 6 in. × 1 in. thick are used for the spars. The method of joining the bracing tubes to the spars is ingenious, as will be seen in Fig. 22. The section on the left is the extrusion. This form of construction is patented by Messrs. Short Brothers (Rochester and Bedford) Limited.

An interesting set of extrusions used on one aircraft is shown in Fig. 23, and it represents one of the most ingenious yet used. Note particularly the spar (top centre), hollow axle (centre), channel sections (right and left centre), and small sections for cabin roofs (bottom left). The channel sections are used to make a variety of fittings for square-tube fuselage and wing drag bracings (Fig. 24). The hollow cantilever-axle section (Fig. 25) is a radical departure from previous practice. The straight length is 15 ft. as delivered, after machining and bending, it is 8 ft. across the legs, the finished weight being approximately 150 lb. Figs. 26 and 27 show sections as used on the "Battle" aircraft by the Fairey Aviation

Fig. 31.—Engine mounting ring circled from section shown in top left-hand corner.

Company Limited., while Figs. 28 and 29 show the method of using extrusions on aircraft constructed by Messrs. Handley-Page Limited.

Apart from sections used by constructors on main assemblies as delivered by manufacturers, there is another aspect which is not exploited by designers as fully as is possible, that is, the substitution of extrusions for machined bars and stampings. Fig. 30 shows seven sections selected at random illustrating this point. It will be readily appreciated that great saving is effected in machine scrap and machine time, the latter being of paramount importance in these days of urgent production requirements.

Since there are dozens of small parts on aircraft which are machined from rectangular, or round bar, a careful study of parts supplied as extruded sections will be time well spent. In view of the large number of type aircraft now being ordered, sections for fittings will be found practicable, even if only a few feet per aircraft are used. If proper study is made of their possibilities, many problems of design will be solved easily and quickly.

Many of the more recent light alloys, now being rapidly adopted on account of their increased strength, notably Hiduminium "RR 56" and "RR 77," are well suited for this purpose. In addition to their relative ease of extrusion, and high strength, their machining qualitities are excellent. Finally, extrusions can be readily manipulated once the correct technique has been acquired. An outstanding example is shown in Fig. 31, which illustrates an engine mounting ring finished to close tolerances.

The author takes this opportunity of expressing his thanks to Mr. A. F. H. Dick, of the Delta Metal Company, for supplying details of the early history of extrusion; to Mr. A. Gouge, of Messrs. Short Brothers (Rochester and Bedford) Ltd.; Mr. A. C. Barlow, of the Fairey Aviation Co. Ltd., and Mr. G. R. Volkert of Messrs. Handley Page Ltd., for permission to publish photographs showing the use of extruded sections in Aircraft constructed by their respective Companies, and to his Company—The Reynolds Tube Co. Ltd.—for their courtesy in granting permission for special photographs to be taken of their processes of manufacture which form the bulk of the illustrations in this article.

The Use of Oxide Films on Aluminium and Its Alloys*

By Dr. E. G. WEST

In this article the author discusses the properties of anodic films, finishing, testing, influence of the base metal, and the general application of anodic films.

Properties of Anodic Films

As indicated, the properties of anodic oxide films vary considerably according to the conditions of formation, and the properties outlined below may be modified for particular requirements.

Appearance.—Each process gives a characteristic appearance to the coating, but, in general, films always reproduce the surface features of the base metal, defects being revealed and the degree of finish accentuated. A metallic sheen is always apparent, being least in the chromic-acid films, and in some cases crystal structure is beautifully shown. More uniform shades are obtained on a wide variety of alloys by the sulphuric-acid process, with A.C., than by any other.

Composition.—The film consists of Al_2O_3 of varying purity, depending on the alloy, and is always hydrated to a certain extent when freshly formed. On drying, water is removed, and the coating finally consists of almost completely dehydrated alumina.

Structure.—All coatings are crystalline but porous, and usually consist of three distinct layers—a hard, thin, compact film, anchored securely to the metal; the main body of the film, with a porosity which may amount to over 40%, and, finally, a non-adherent layer of oxide (appearing as a "bloom"), which may be removed by rubbing or light buffing. This last is not always present, and is usually a sign of over-anodising.

Corrosion Resistance.—Alumina is insoluble in most reagents, and anodic films have a high resistance to corrosive media, with the exception of chlorides, which cause pitting at a rapid rate. The corrosion resistance is increased many times by impregnating the coating with such substances as lanoline and waxes, and treatment of the film with corrosion inhibitors, such as chromates, has also been employed.

Hardness.—The average hardness of anodic films is about 8 on Mohr's scale; that is, it approximates to quartz. It varies through the film, as shown by the figures given by the Bierbaum test[18] for Alumilite films formed under different conditions: Face of film, 180 to 140; centre of film, 3,000 to 1,200; base of film, 5,000 to 1,500. On the same scale, glass gives a figure of 2,000, and the metal aluminium 80.

Toughness.—Although hard anodic films are very tough, and usually exhibit great elasticity, this decreasing as the thickness of the film increases. A friable film is exceptional, and, as the film is built up from the metal, flaking or spalling is almost unknown, although cracks may appear on very severe working.

Electrical Resistance.—The resistivity is very high, potentials of over 1,000 volts before breakdown being withstood by many films, but the resistance of the dried film decreases as the relative humidity increases due to the retention of moisture within the pores. The film also possess rectifying properties; indeed, the modern development of the film owes its inception to the early workers in this field, but little use is made of this characteristic to-day.

Adsorbtive Power.—The porous nature of the film makes it ideal for retaining a great variety of substances, such as oils and greases, chemicals, colouring matter, lacquers, etc. The permeability of the coating varies, as would be expected from its structure, the inner layer being less adsorbtive than the main layer. This property makes the film the best basis for painting or lacquering aluminium surfaces, on which it is normally very difficult to secure adequate keying action.

Colouring.—Aluminium oxide acts as a "Mordant" in reactions with certain dyestuffs to produce permanent colours, known as "Lakes." This property, the use of which is covered by one of the original Bengough patents,[19] enables the film to be coloured any desired shade, and the high-adsorbtive capacity affords a second method of obtaining this result. Both methods are used, and frequently a combination of each is involved.

Heat Resistance.—The film withstands heat to a remarkable degree, no change taking place in the oxide below 800° C., and it is possible to fuse the base metal, retaining the molten mass in a skin of oxide.

Reflectivity.—The reflectivity of the coating is very high. exceeding that of chromium on suitably prepared surfaces, Thin films on polished aluminium give specular reflection, while thicker coatings, particularly on matt surfaces, have a very high diffused reflectivity.

Finishing Operations

The operations of finishing the work after removal from the anodising vat depends on the application of the articles, but the sequence which must be followed is: (1) Swilling, to remove all electrolyte; (2) colouring, when required; (3) sealing the film; (4) removal of the non-adherent layer, if present.

Colouring.—There are relatively few dyes which react with Al_2O_3 as a mordant, but these give the best resistance to leaching, and certain of the Solway and Alizarin colours possess very good fastness to light. The adsorbtion principle is used with organic dyestuffs and inorganic salts, and a very large number of substances may be used in this way. The suitable organic dyes are in the mordant, acid, acid-mordant, direct and chrome classes, basic and vat dyes being unsatisfactory, as they frequently attack the oxide. The fastness to light is a property of the dye itself, but the moisture resistance depends on the nature of the film, method of application, and the effectiveness of the subsequent sealing treatment.

Coloured inorganic salts confer the highest light fastness, but they do not resist leaching to any considerable extent. An interesting method of producing the required compound involves the adsorbtion of a substance by the film, followed by treatment with a second solution, to give a coloured precipitate within the pores.

Mere colouring of anodic films is quite simple, although exact matching is often impossible, and very few shades have yet been produced with completely satisfactory resistance to both light and moisture. Rigid control of the anodising conditions, as well as control of the dye mixtures and dyeing conditions, is essential, and the method adopted for sealing must be suitable for the required application and for the dyestuff used. Lacquer, as a thin transparent film, is often employed to protect coloured films, enabling many new outlets to be exploited. A recent paper by Henley[20] summarises many of the

* Continued from page 139, February issue.

18 Mandeville. *Metallurgist* (supt. to Engineer). August. 1937. 60.

19 Brit. Pat. No. 223995.

20 Henley. Paper to the London Section of the Society of Dyers and Colourists. November. 1937.

latest developments in the technique of colouring, but more active co-operation between the experts of the dye industry and those engaged in anodic oxidation is imperative for the extension of the process in this direction.

The films produced by the chemical processes may also be coloured if they are of sufficient thickness, this possibility being covered by a patent.[21] A pleasing iridescent effect is frequently achieved by chemical films, without dyeing, due to their extreme thinness, and the same finish may also be imparted by suitably modifying the electrolytic methods.

Sealing.—Sealing of anodic coatings is now universally practised, but some confusion has arisen over this term. There are two distinct methods, and they may be applied singly or together.

The first, mentioned by Bengough, depends on the adsorbtion properties of the film, and consists of filling the pores with a substance to assist in corrosion prevention. This is distinct from surface painting or lacquering over the oxide, the usual impregnating agents being of an oily or greasy nature, lanoline dissolved in white spirit being the commonest.

The methods later described involve altering the physical nature of the oxide layers, amounting possible to a definite crystallographic change, and some form of heating is required. High-pressure steam (60/80 lb. per sq. in. for 30 mins.), or boiling in water or other liquids are the usual means employed, and have been described by many workers.[22] Such processes increase the mechanical strength and corrosion resistance of the film, but the power of adsorbtion is greatly reduced. The impregnation of the film with grease, etc., completely prevents dyeing, while steam-sealing renders the operation of colouring much more difficult. As long as the colour is not affected by the sealing process, it is therefore usual to seal after or during dyeing.

Testing of Anodic Films

There is a lamentable lack of data on this important aspect of anodic oxidation, specifications being almost non-existent, and the majority of the methods in use for routine testing have been devised to meet particular requirements, with the result that there is a great deal of specialised equipment employed independently. A number of descriptions of testing apparatus have appeared from time to time, one of the most recent being by Fischer,[23] but the most important contribution has been made by the A.S.T.M., a review of the findings of the Sub-Committee having just been published.[24]

The film may be separated from the base metal by solution of the latter by several reagents, two excellent methods being due to Sutton[25] and Wernick.[26]

The thickness of films is obtained either by direct microscopic measurement of a polished cross-section or of a detached coating, or, alternatively, by micrometer measurement of the article before and after removal of the oxide by a suitable solution. The dyeing of the film by a standardised method is of great assistance when the microscope is used in the examination of coatings. Corrosion resistance is estimated either by the standard salt-spray test, or by immersion of specimens in saline solutions, or the corrosive media which they are required to withstand in service.

The hardness of oxide films must be obtained by one of the scratch methods, using a diamond point; while wear-resistance tests involve the use of an arbitrary abrasion method, of which there are many, a recent one being due to Mauksch and Budiloff.[27]

Di-electric properties are measured by exploring the surface with a suitable electrode under standardised conditions, the circuit being completed through the base metal by means of a point piercing the oxide skin. Heat resistance and light reflectivity are computed by the normal physical laboratory methods.

Coloured films are often subjected to fadeometer and leaching tests; but while comparative results may be given by these standard methods, the only reliable data can be obtained by exposure under service conditions, where the many natural variables can exert their influence. The adoption of such exposure tests would have prevented many disappointments during the last few years.

The Base Metal

The important influence of the base metal on the efficiency of anodic oxidation has already been stressed, and although the best oxide films are formed on pure aluminium, a large proportion of the alloys in use to-day can be successfully treated. The usual range of composition for economic anodising does not exceed 10% added elements, and the sulphuric-acid process is best employed if the aluminium content is less than 95%.

In general, the structure of alloys most suitable for oxidation consists of a single phase or two aluminium-rich solid solutions, insoluble metals and compounds being attacked during treatment, with increase in the current density. Such alloys give the film a patchy appearance and considerably reduce its resistance to corrosion.

The usual limit for copper is 2%, but up to 5% is allowable, while the manganese or iron should not exceed 2%. The least deleterious elements are magnesium and zinc, either of which may be present up to about 5%; but silicon is always harmful. It causes abnormally high currents and the resultant film is dark, with a considerable proportion of non-adherent oxide and silicon or its compounds. The 12% alloy has been treated but without appreciable advantage, and the maximum silicon content should not exceed 3 to 4%.

Duralumin and "Y" alloy are readily anodised, but the die-casting alloys have not yet proved amenable to the electrolytic processes. Alloys most suitable for treatment exhibit unsuitable die-casting properties, such as hot shortness, while the casting alloys contain excessive amounts of the elements that trouble the anodiser. An interesting patent[28] proposes to control the colour of the film on a range of die-casting alloys, by controlling the analyses so that magnesium and zinc are the principal additions in the proportions of the compound $MgZn_2$. The combination of die castings and anodic oxidation should greatly increase the scope of each.

In general, heat-treated and worked material is easier to deal with than castings, any cracks, pores, or even subcutaneous holes in the latter being a constant source of rejection after oxidation. The presence of welded or built-up metal is also undesirable, as rapid attack occurs.

Anodic oxidation has no effect on the physical properties of the base metal, but by virtue of its corrosion resistance it exerts a beneficial influence in reducing corrosion fatigue, especially when supplemented by lanoline, lacquer, etc. After normal treatment no difference in size is apparent, thus enabling final dimensions to be attained before anodising.

Applications

Many uses of anodic films have already been suggested, and new applications are constantly being published. The employment of anodised surfaces depends usually on one or more of the following requirements: (1) Corrosion resistance; (2) abrasion resistance; (3) electrical resistance; (4) decoration.

Among the minor uses two typical ones may be noted—its resistance to heat coupled with its high radiating power, especially when coloured black, fits it for reflectors in various types of heat radiators. The power of adsorbing chemicals is employed in the production of a new plate for photographic work, thin sheet aluminium being anodised before impregnation with the required emulsions.

21 U.S.A. Pat. No. 2001427.
22 For example—Setoh and Miyata. Bull. Inst. Phys. Chem. Res. Japan. 1929. 2. 105 Brit. Pat. No. 474609.
23 Fischer. *Aluminium.* 1937. 19 (6). 358.
24 Review in *Aluminium and Non-ferrous Review.* Sept., Oct., Nov. 1937.
25 Sutton and Willstrop. *J. Inst. Met.* 1927. 38. 259.
26 Wernick. *J. Electrodep. Soc.* 1934. 9. 162.
27 Mauksch and Budiloff. *Aluminium.* 1937. 19 (5). 298.
28 For example—Gerard and Sutton. *J. Inst. Met.* 1935. 54. 29.

(1.) *Corrosion Resistance.*—Anodic oxidation has been specified for aircraft components for many years, and its use has been extended to a great many marine fittings, including cabin lights, port-hole frames, etc. Many of the present architectural uses, such as window frames, rely on the high corrosion resistance, particularly as the film affords an ideal surface for paint and lacquer. The extension of anodic finishing into the transport world has barely started, but the realisation of the obvious advantages of freedom from corrosion, coupled with the engineering advantages of aluminium alloys, should not delay a change-over in the near future. Many of the uses in the home, in hospitals, in offices, and in places of entertainment depend on the resistance to attack, while the recent employment of anodised aluminium vessels for the preparation of pure chemicals strikingly emphasises this property.

(2.) *Abrasion Resistance.*—The outstanding example of the use of anodic films to resist wear is in the treatment of pistons for internal combustion engines; but this application also makes use of the other properties. The resistance to corrosion is of equal value, especially as the high electrical resistivity prevents electro-chemical attack, while the advantages accruing from the adsorbtion of lubricants by the film are obvious. Another interesting use depending on wear resistance is the humble knitting pin, which must withstand very drastic abrasion.

(3.) *Electrical Resistance.*—Although electrical engineers first exploited anodically formed films in surge-arresting apparatus, interest in the newer applications does not yet appear to be fully awakened. Undoubtedly there will be considerable quantities of aluminium used for conductors, with an oxide film as insulation; but sealing is necessary to avoid absorbtion of moisture, of course. Early experiments have shown that considerable saving in the weight and size of motors, and generators can be made by the employment of oxidised aluminium against insulated copper, while the allowable temperature rise can also be increased.

(4.) *Decoration.*—Coloured aluminium has already initiated a revolution in the ideas of architects and other designers, and in spite of certain early failures the use of anodic coatings in such buildings as Broadcasting House and the Shakespeare Memorial Theatre has focused deserved attention on its possibilities. Public buildings, offices, shops and domestic buildings now employ coloured anodised aluminium for interior decoration and external design, in addition to a multitude of utilitarian fittings. Other applications which depend for their appeal on decorative grounds are toys, personal articles such as vanity cases and cigarette cases, novelty fittings, sports gear, bicycle parts, picnic outfits, pencil cases, etc.

Riveting Methods and Rivet Equipment Used in German Light Metal Airplane Construction

Economic factors are increasing in importance in the design and construction of aircraft, and in a recent lecture before the Royal Aeronautical Society Dr.-Ing. Wilhelm Pleines emphasised the importance of the riveted joint as the most useful permanent connection, and discussed modern methods and equipment, brief reference to which is given in this article.

ALUMINIUM alloys, particularly the Al-Cu and Al-Cu-Mg alloys which are capable of improvement by heat-treatment, are being increasingly used in aircraft construction. For the permanent connection of structural parts the rivet is the most reliable and safest connecting element. Experience has shown that best results are obtained when the rivets are driven cold, and for this purpose various tools, machines and riveting methods have been developed to obtain the most satisfactory results, and detailed information regarding these questions will be of interest.

Rivets are generally used in relatively small sizes; for structural parts of "stressed skin" construction, the rivets are generally between 2·5 and 4 mm. The number of rivet sizes between 4 and maximum 10 mm. diameter is relatively small. Rivets from 5 to 8 mm. are used principally for structures with comparatively thick walls. The special "open" design of these parts enables the use of machine-riveting methods. In addition to aluminium alloys of the types mentioned, materials of the magnesium-alloys group, such as Elecktron, are also riveted cold. For highly stressed Elecktron parts, $H\gamma_3$ and $H\gamma_5$ rivets are used in order to avoid corrosion, while for parts which are submitted to little stress pure aluminium rivets are used.

Most of the rivet materials now used consist of strain-hardening alloys, and their workability and forming characteristics can be increased by heat-treatment just before driving. The heat-treatment includes three stages: annealing, quenching and ageing. Annealing is mainly done in a salt-bath with a constant temperature of about 505° C. Care is necessary to limit the variation of temperature to ± 5° C. Sorted in equal sizes the rivets should be placed in the bath in perforated or wire baskets to ensure uniform heating. From practical experience it is suggested that the following periods are required for annealing different rivet diameters.

Rivet diameter in mm. ..	2—4 ..	5 ..	6
Heating time in minutes ..	10 ..	15 ..	25

The rivets should be quenched in cold water at room temperature, and the time interval between removal from the furnace to quenching should be as short as possible. After quenching, the rivets should be dried and stored free from moisture to avoid corrosion risks. When a nitrate bath has been used for heating it is essential that any adhering nitrate particles should be washed off the rivets for which warm—not hot—water should be used. The working characteristics in the normal heat-treated state vary in inverse order to the physical properties. When driven within two to four hours of quenching, the rivets remain soft enough, after this time the age-hardening of the material develops at a more rapid rate, and diminishes the workability. The actual riveting procedure does not interrupt the increase of the physical characteristics which can be expected when ordinarily stored within four or five days. On the contrary, it has been shown that certain methods of cold forming, squeezing for instance, increases the shear strength of the riveting material.

Due to the fact that the workability in the normal heat-treated state varies in inverse order to the physical properties, and also owing to the fact that ageing proceeds rapidly after quenching, in Germany the rivets are driven within the first one or two hours, and in U.S.A. only half an hour after quenching. In both Germany and U.S.A. there is a tendency to develop special rivet-metal alloys in which age-hardening at room temperature is retarded to a greater extent than the alloys now in common use. The alloys developed for this purpose have a lower ultimate shear strength than the standard values for the normal self-hardening alloys, but it is probable that strength alone is not a deciding factor.

Percussion and Holding-on Tools

Owing to the custom of carrying out riveting on rather complicated aircraft structures only when these are fitted in special devices, hand riveting is still practised, but the hand hammer is not used. Special light hammers have been developed, operated mainly by compressed air. In pneumatic riveting the right proportion of the percussion power or impact of the hammer (number and strength of blows) to the size (mass) of the dolly is of fundamental importance for economic riveting. Hammers of too light a weight and with too high a number of blows are frequently used for driving of strong rivets. It should be remembered that the weight of the dolly and its mass distribution decide to a great extent the unavoidable loss of intended forming work through the transmission of energy, because part of the blow is used to move the mass of the dolly at driving. Tests should therefore be made to determine the most favourable working conditions for every structural part. It would be a mistake to use light pneumatic hammers with a high number of blows for the driving of strong rivets, because too high a number of blows at low single-blow impacts produces an elastic rather than a plastic forming ; they tend to peen the head without upsetting the shank. In consequence of this the rivet shank end undergoes local hardness increase, if cold driving is done. The failures due to this are : formation of cracks at the closing heads or, later on, fracture of the brittle closing heads, even if riveting joints are subjected to low static loads. It is also obvious that the natural characteristic of workability of the rivet materials have a considerable influence on the result.

The majority of pneumatic hammers actually in use belong to the multi-blow class and are particularly suitable to flush riveting. In practice so-called " indirect " riveting has proved to be advantageous, by which the set strikes the head of the rivet, inserted from outside mostly, while the holder-on, held against the free shank end, forms the closing head through the motion transmitted by the hammer blow. For this method of riveting the correct ratio single impact to holder-on mass is highly important if the best transmission of energy is to be obtained. Owing to the fact that careful operation of the pneumatic tools is necessary, modern multi-blow compressed-air hammers are excellent because of their fine regulation of initial blows. They are fitted with air throttling devices to govern the impact of blows.

For stronger rivets, say, for diameters of 5 to 10 mm., especially for structural parts of high rigidity and relatively great extent, pneumatic hammers for slower but heavier blows have proved to be very successful. Slow-hitting hammers are preferred where noise is to be reduced. The change-over to so-called " open " designs of air-frame structures with good accessibility to all riveting points allows the use of heavy hammers, partly designed as stationary machines, and partly as portable machines, capable of being suspended by rope tackle blocks with counterweight in order to permit maximum production with minimum fatigue.

Machine Riveting

During recent years so-called " open " designs, with accessibility from both sides, has been increasingly adopted in aircraft construction, and a steadily-increasing demand for portable and stationary riveting machines has followed. The majority of existing machines serve exclusively for driving rivets. The weights of all these machines are rleatively high, and they can therefore be used only if suspended. These high weights are due to the bows which must be of a solid and rigid design, especially if the riveting machines are squeezers. The one-shot system has proved to be of great advantage, because the driving effect and transmission energy from the percussive tool is brought about rather by dynamic effect. By the application of such machine tools a better utilisation of energy is attained, and furthermore, a uniform adaptability of operations to the respective structural conditions and an improvement of the riveting work in its technique. Modern aircraft, however, is already past this stage of design development. Actual light-metal construction types require more rapid and low-cost production in riveting, and better and more uniform riveted joints than formerly. Interest is, therefore, directed especially for rapid quantity production, to appropriate riveting machines capable of performing automatically all operations required for riveted joints.

Owing to the fact that the strength of the skin is relatively high, seams and laps must be riveted with narrow spacings. As the diameter of rivets is no more than 3 mm. mostly, and as the inner stiffeners of the skin must be riveted near to each other, the number of rivets to be inserted into the skin will be the higher the more the skin is designed for aerodynamic reasons, and for the transmission of stress. Machine riveting saves a considerable amount of time, especially for riveting of stressed skin parts.

Needless to say, for a comprehensive application of automatic riveting machines, in order to reduce manufacturing cost, parts should be designed to accommodate themselves to the special disposition of such machines. Many existing designs are unsuitable for this, while others, thanks to their simpler structure, facilitate production, without the restriction of the requirements regarding strength.

The Multelec Recorder Controller

The Multelec recorder-controller, which is based on the potentiometer principle, is claimed to be of extreme sensitivity and great relay power, and is used for temperature recording and control for annealing and reheating furnaces and soaking pits ; all types of tempering, carburising and heat-treatment furnaces ; open-hearth furnaces ; blast-furnaces—where the long stretches of compensating lead do not affect the instrument and allow it to give complete records of stove operation, blast-temperature control, and the recording of cold-blast and waste-gas temperatures —and for such other applications as vulcanisers, cookers, pasteurisers and refrigeration plant.

It is also widely used for continuous recording of pH values and can be supplied with three types of primary element to suit different locations ; for measurement of electrolytic conductivity, and for CO_2 measurement, in which latter case the primary element is built on the thermal conductivity principle, and responds immediately to changes in the CO_2 percentage.

The Multelec incorporates a galvanometer of extreme sensitivity, the deflection of which is used through a double relay action to set up a powerful mechanical force for the actuation of various kinds of controls.

For temperatures up to 500° C. the recorder has a Wheatstone bridge circuit, and uses resistance thermometers with platinum or nickel coils, and for temperatures above 500° C. thermo-couples are used. These couples can be made in iron-constantan, chromel-alumel, platinum-platinum-rhodium, covering all ranges up to 1,600° C.

Features of the Multelec include potentiometer principle, automatic cold junction temperature compensation, frequent automatic current standardising (the bridge potential is standardised every 54 minutes, compensating for the drainage of the batteries), extra robust galvanometer, and high-frequency measuring cycle by which a change of temperature is shown on the chart within two minutes of its occurrence.

Multi-point instruments are offered ; there are pneumatic and electrical automatic controls, the latter working on either the simple " on-off," or the " floating " methods.

Full details of this interesting instrument are given on a new publication issued by the manufacturers, Messrs. George Kent Ltd., of Luton, Bedfordshire, whose London Office is at 200, High Holborn, London W.C. 1. The title of the new booklet is *The Multelec.*

Practical Spectrographic Analysis

Four useful accessories, which have increased the sensitivity, rapidity and accuracy of spectrographic analysis, have been developed which are briefly described.

SPECTROGRAPHIC analysis has been developed considerably during recent years, and appropriate analytical spectral sources and methods are now used for the analysis of various chemical and metallurgical materials. The use of special equipment and technique has increased the sensitivity, rapidity, and accuracy of these analyses, and four useful accessories have been developed in the laboratories of the Dow Chemical Co. by J. S. Owen.* These accessories are the purification of graphite rods for use as spectroscopic electrode supports by the use of high-temperature electrical heating in vacuum, the development of a spectral source alignment pointer, the application for analytical purposes of the A.C. arc as a spectral source, and the development of a graphical plate calculator for the conversion of micro-photometer readings into percentage concentrations.

Commercial graphite of spectroscopic quality contains appreciable amounts of iron, silicon, boron, magnesium, calcium, aluminium, copper, titanium, and vanadium. Graphite containing considerably smaller amounts of these materials can be obtained, but its purity is not completely satisfactory and its cost is considerable. Since the use of impure graphite electrodes introduces a probable source of error in the analysis of many materials, several methods of purification have been developed. The latest method of purification consists of heating at a temperature of 2,460° C. or higher in an evacuated furnace, and has resulted from a series of tests on the effects of variations in temperatures from 2,000° C. and variations in the time of heating, and of the use of different degrees of vacuum and different gases such as air, nitrogen, helium and hydrogen as a medium surrounding the graphite.

Graphite of greater purity than that of the best spectroscopic graphite previously commercially available can be produced by this method of purification, which removes from the commercial graphite rods of spectroscopic quality calcium, copper, aluminium, titanium and vanadium completely and all but the very slightest traces of iron and silicon, but does not remove boron. Graphite so treated contains less iron, silicon, calcium, and copper but more boron than the purest commercial product and neither contains aluminium, titanium, or vanadium. Graphite rods so purified may be used with safety as electrode supports for the analysis of materials for any element except carbon and boron, even when sources of the highest sensitivity possessed by the A.C. arc and the cathode layer of the D.C. arc are used.

Various types of analysis require the use of different types of electrode holders having different locations of the spectral sources. This prevents the use of fixed holders in which the electrodes are in constant alignment, so that the new alignment pointer in which the spectral source is located at the desired distance from the spectrograph slit, and which is aligned vertically and horizontally and the electrodes properly spaced not only conserves time but also ensures accuracy.

In order to maintain high analytical efficiency considerable effort has been devoted to the development and refinement of spectral sources most suitable for the analysis of different types of material. Sources now in use consist of condensed sparks powdered by 1 kva., 25,000 volt and 10 kva., 50,000 volt. transformers, the D.C. arc, the cathode layer of the D.C. arc, and the A.C. arc. The applicability of the A.C. arc for analytical purposes has been demonstrated successfully, and the advantages of this spectral source make it appear to be of great industrial importance for the analysis of chemical materials. These advantages include ease of maintenance, ease of control of excitation conditions, high sensitivity, and low background density and accuracy.

A comparison of the spectral sensitivities of detection of impurities present as traces in some representative materials give the following results. The sensitivity of detection in the A.C. arc and cathode layer sources of iron, silicon, manganese, calcium, aluminium, strontium and copper in sodium hydroxide are comparable, that in the D.C. arc is somewhat less. The sensitivity of detection of vanadium in sodium hydroxide is comparable in the A.C. arc and the cathode layer, but is five-fold lower in the D.C. arc. The sensitivity of detection of phosphorus in sodium and phosphate solutions and of silver in sodium chloride solutions is from five to ten fold greater in the A.C. arc than in the cathode layer and the D.C. arc. In the spectra of all of these materials the background density is much lower in the A.C. arc than in the other sources. In general, the sensitivity of detection in the A.C. arc of any metallic constituent of a chemical material is of the order of magnitude of 0·0001%.

On the basis of these representative analyses and of others, it is concluded that for the analysis of many industrial chemicals the sensitivity of the A.C. arc is comparable with, or greater than, that of the cathode layer, while that of either is, in general, greater than that of the whole D.C. arc. Neither the A.C. arc nor the cathode layer, however, shows, in general a greater sensitivity for the analysis of solid alloy electrode than does the D.C. arc. The advantages of the A.C. arc over the cathode layer for quantitive analysis consists of much weaker background radiation, the uniformity of line intensity throughout the entire usual arc length, and the elimination of any optical system for accurately focusing a restricted portion of the arc upon the spectrograph slit.

The graphical plate calculator increases the speed of quantitative analysis in which an internal standard element is used by reducing to a single graphical step the conversion of spectral line blackenings, obtained with a microphotometer, into percentage concentrations of the element under analysis. The blackenings of the spectral lines and of the steps of the intensity calibration pattern obtained by the Hansen step-diaphram are measured with a microphotometer. The characteristic curve of the photographic plate is obtained by plotting the blackenings of the steps of this pattern against the logarithms of the corresponding light intensities, and then drawing the curve on squared paper and measuring by an appropriate analytical scale for the element under analysis. An analytical scale is made from the analytical curve for the analysis of the material for each element by projecting the ordinates in percentage concentration of A upon the abscessæ in log $\frac{I_S}{I_A}$, the logarithm of relative intensity of the comparison spectral line pair, where S is the internal standard element and A is the element under analysis. Continuous use of this apparatus in routine production control analyses of magnesium alloys for zinc has shown that this method is at least twice as rapid as arithmetical conversion, that it yields an analytical precision equal to that of arithmetical conversion, and at the same time decreases the probability of arithmetical error.

**Metals and Alloys*, 1938, vol. 9, No. 1, pp. 15-19.

Reviews of Current Literature

Swedenborg's Treatise on Copper

The British Non-Ferrous Metals Research Association, in co-operation with the Swedenborg Society, will shortly publish a translation of Swedenborg's famous treatise on Copper, "De Cupro," originally published in latin in 1734. No translation has hitherto appeared. This book gives an account of the smelting and refining of copper as practised in many countries at the time ; the production of brass ; the nature of copper ores and their assaying ; and various other matters pertaining to the properties of copper, its alloys, and its history.

The translation will appear in bound mimeographed form, in three parts, totalling about 550 pages. The publishers wish to bring the translation before the scientific public and others interested at the lowest possible price. On this account, the illustrations in the book, comprising numerous plates are not reproduced. Communications on the subject should be addressed to the British Non-Ferrous Metals Research Association, Regnart Buildings, Euston Street, London, N.W. 1.

Magnesite as a Refractory

The two broad classifications of steel-making practice to-day, exclusive of crucible melting, can be considered as acid and basic. The basic process is dependent upon the refractory linings, whether the process be via open hearth, electric furnace or Bessemer converter. Improved open-hearth and furnace practice, and the big advance in coreless induction furnace melting technique have favoured the return of basic Bessemer steel, and these have been made possible by development in furnace refractories.

Magnesite gives excellent service as a furnace refractory in open hearth, converter and electric furnaces, and also in continuous reheating furnaces, but the results of research in furnace refractories, has not been readily available to metallurgists, melters, or to furnace designers and builders. For that reason, the publication of a book devoted to magnesite as a refractory, edited by Dr. Percy Longmuir, should be of great value to all concerned with the design, construction and operation of furnaces.

The 12 chapters deal with early experiments with magnesite as a refractory—with useful reference to nomenclature of magnesite and its products, in which it is shown that the oxide $MgCO_3$ is magnesia, chemically speaking, this description is generally reserved for the product obtained by chemical process, and that when the mineral is directly calcined the term magnesite is accepted as sufficient—describe compact and crystalline magnesite ; sources of the raw material, calcination considerations and methods, the manufacture af magnesite bricks, firing of the magnesite bricks, the chemical and physical properties, very useful data concerning electrically-fused magnesite, the use of magnesite in the steel industry, and also other refractory uses, and magnesite in the British Empire.

The book is indexed, illustrated and contains two appendices, one dealing with chemical composition and the other giving references.

Although the British Empire has good supplies of the compact variety of magnesite, it is less fortunate in respect of the crystalline mineral, the commercially-important deposits of the compact form being found in British India, Australia, South Africa and British Columbia. External sources are Greece and California, and in parts of Central Europe and Asiatic Turkey. Crystalline magnesite occurs in Canada, Anglo-Egyptian Sudan, Chewalah (U.S.A.), Manchukuo and Southern Norway, whilst the best-known sources of breunnerite are those in Austria, and there are extensive deposits in Russia, this country now being the world's chief producer of refractory magnesite.

It is shown in this book that magnesite bricks have a much greater resistance to external crushing force when cold than have other refractories, but are not so strong under load at high temperatures as, for instance, silica bricks.

This is recommended as a valuable and interesting publication on a subject upon which a relatively small amount of literature hsa been published.

By A. W. Comber, F.I.C., Ass.Inst.M.M. Published by Charles Griffin and Co., Ltd., London. (No. 8 of this company's *Industrial Textbook*.)

Journal of Institute of Metals

Volume LXI (Proceedings), No. 2, 1937.

The latest volume issued by the Institute of Metals consists, essentially, of a record in permanent form of the proceedings at the recent Sheffield meeting, together with additional papers not read at that gathering.

Undoubtedly, the most topical of the communications now reproduced is the Autumn Lecture on "Metallurgy and the Aero Engine." Contributed by Dr. D. R. Pye, C.B., F.R.S., Director of Scientific Research, Air Ministry, it shows the wonderful strides that have been made recently in air-engine design—largely as a result of the work of the metallurgist. Thus, an engine which in 1929 gave power for "take off" of 460 h.p., now gives (for the same dimensions) 1,010 h.p.

The purely metallurgical papers included in the present volume cover a wide field, as is indicated by such titles as "The Methods of Testing Zinc Coatings," "The Mechanical Properties of Some Metals and Alloys Broken at Ultra High Speeds," "Precision Extensometer Measurements on Tin," and "Alloys of Magnesium." A Swedish engineer, Dr. Hermann Unckel, contributes a valuable paper dealing with the effect of cold rolling on the structure of alloys.

Edited by G. Shaw Scott, M.Sc., F.C.I.S., London : The Institute of Metals, 36, Victoria Street, Westminster, London, S.W. 1. £1 11s. 6d.

Manual of A.S.T.M. Standards on Refractory Materials

The 1937 Manual of A.S.T.M. Standards on Refractory Materials gives in their latest form all of the specifications, test methods, and definitions in this field as developed by the American Society for Testing Materials. In addition to all standards, the detailed methods for interpretation of refractory test data are included ; there are comprehensive surveys showing service conditions of refractories in important consuming industries, and details are given of the standard samples of refractory materials.

Specification requirements cover various types of fireclay brick, ground fireclay, and other refractories. The test methods include chemical analysis, cold-crushing tests, high-temperature heat insulation, tests for resistance to spalling, particle size, permanent linear change after reheating, porosity, and permanent volume changes, and pyrometric cone equivalent. An important new section is intended as an aid in the design and operation of furnaces lined with refractories—this covers a recommended procedure for calculating heat losses through furnace walls.

The latest methods for interpretation of refractory test data incorporate numerous revisions and amplifications. Detailed tables give the composition of the standard samples of refractory materials developed in co-operation with the National Bureau of Standards and interested laboratories Comprehensive surveys have been made of conditions of refractories in the following industries : open-hearth practice, malleable iron industry, copper industry, lead industry, by-product coke-ovens, and glass industry. The last-named survey included in the publication for the first time, covers refractory service in the glass industry as it pertains to continuous bottle furnaces.

Copies of this 180-page publication can be obtained from A.S.T.M. Headquarters, 260 S. Broad Street, Philadelphia, at $1.25 per copy, in heavy paper cover, with special prices on orders for ten or more copies.

Non-Destructive Testing

Many materials used in engineering are made to specifications that involve the making and breaking of test pieces ; for many purposes this method is not satisfactory, and increasing use is being made of non-destructive methods which were described by Mr. J. P. Reed, at a recent meeting of the Midland Metallurgical Societies. His views on the subject are summarised below.

TESTING by the normally accepted methods is still handicapped by the need for assuming that all the articles purchased will behave as the test piece indicates in the destructive test. Thus, it will be readily understood that much attention has been focused on the development of non-destructive methods. This means that tests involving mechanical work must give place to purely physical changes of a temporary character, and brought about by such agencies as have no effect on shape or structure. The field is confined, for the most part, to magnetic, optical and electrical lines of attack. The object is, of course, to learn as much as possible by non-destructive methods, of the properties of materials that ordinary destructive methods will reveal, such as strength, hardness, uniformity, etc.

The schemes for non-destructive testing discussed have, with a few exceptions, come within the experience of the research department of Tube Investments Ltd. This department has throughout been concerned with tests that detect not only such faults as would ordinarily be found in an acceptance test, but also in detecting faults that cannot be found by existing methods, but which might lead to unsatisfactory service by the part concerned. Primarily, these were concerned with tubes, mainly steel, and hence, mainly magnetic. It should be remembered that the stainless 18-8 nickel-chrome steels are austenitic, and therefore non-magnetic in the normally accepted sense of that term. In such tubular materials faults consisting of very thin elongated non-metallic inclusions may only constitute one hundred thousandth of the cross-sectional area of the tube, but could cause serious trouble in such an operation as expanding. A satisfactory non-destructive test would enable every portion of the tube to be examined in a routine manner.

The relationship between voltage and the magnetic flux is a property that has proved most useful to investigators of non-destructive testing methods. In a magnetic material, any discontinuity or local physical change of structure may cause this phase relationship to change. If, therefore, one has sensitive instruments to detect this phase change, the only thing left is the precise interpretation of it. From their nature electrical methods would be expected to be capable of indicating deep-seated flaws as well as those on or near a surface. Sperry, in America, developed a direct current method for testing rails for transverse flaws, and a test-car was fitted up for use on the railway system. His scheme was tried out by this department as far back as 1931, and found that owing to the difficulty of getting constant resistance values at the brush contacts, the method was quite useless, and all kinds of spurious changes were measured, varying continually over the same length of material. Sperry was probably satisfied because the defects in his rails were large compared with the tiny defects that were being sought for in electrically-welded tubing.

If alternating current is used for energising a surrounding coil, circumferential eddy currents can be produced. A surrounding search coil will now detect changes in the eddy currents, and in fact two search coils can be balanced against each other and any out-of-balance conditions caused by non-uniformity detected by a suitable instrument. This scheme presented a host of variables which swamped any correlation of the welded tubing with routine standards under which the tube has been satisfactorily produced for many years.

In conjunction with the British Thomson-Houston Company an associated company has investigated the possibility of using an audio-frequency test in the examination of electrically-welded tubes. It was found that, owing to the inaccuracy of human audibilities, the limits of error were much too great. A mechanical test of greater accuracy was tried, consisting of oscillating the tube torsionally by clamping one end of the tube to and co-axially with an alternator. The other end was loaded with such a mass that it would resonate at 50 cycles per second. Oscillations were obtainable in the tube of such magnitude that the corresponding shear stress approached 19 tons per sq. in. The results, however, shewed no correlation with weld strength, presumably on account of the relatively low stress imposed upon the weld itself, as distinct from the large shear stress in the wall of the tube.

X-rays including X-rays from radio-active material are useful for the inspection of parts likely to contain large cavities or inclusions of non-metallic material. They do not, however, enable thin fissures and filaments or laminæ of non-metallic matter to be detected with certainty below a limiting size for any given thickness of metal. It would be safe to say that for routine inspection of mass-produced material X-ray inspection is not likely to be either satisfactory or economic. There is the added difficulty that a thin lamina may lie edgewise to the X-ray beam and cast practically no shadow, although its dimensions at 90° to that plane may make it a serious defect.

The Magnetic Analysis Corporation of America sell an apparatus depending for its action upon the magnetic properties of iron. This apparatus, it is understood, is at present restricted to bars and tubes up to 4 in. diameter. It is claimed that cracks or flaws are seen by a change in wave form occurring in a standard piece. The variations which will affect the ultimate wave form are dimensional variations, changes in magnetic permeability due to slight changes in heat-treatment or subsequent cold work, and physical unsoundness. The query that remains is the inevitable one as to how one can be sure of a standard bar, unless it has been non-destructively tested on an already approved method, or thoroughly destructively tested in the good old way, by which time there is no standard material left.

Methods utilising purely magnetic inspection are limited to defects of such a character that they give rise to distortion of a magnetic field set up in the material. The method is an ideal one for the inspection of polished surfaces containing fine cracks normally invisible to the eye. That is not to say that rough, scaled or machined surfaces cannot be examined by this method, but more care is necessary and a little more skill may be required. Subcutaneous or internal defects may be detected in this way, but this depends upon the amount of magnetisation applied to the material and to the location and size of any faults existing.

In July last, Holtschmidt published a paper in Germany, dealing with the magnetic method, using iron powder for detection of faults. He stated that in this method various anomalies had been observed. In some cases crankshafts had been rejected because of definite indications that cracks or inclusions existed within the shafts, but micro-sections

had proved that such cracks did not exist. Some two or three years ago, an associated company had made some aero push-rods for a Continental firm, which were actually cold-drawn tubes. They were rejected almost wholesale as a result of routine examination by means of the magnetic ink-spraying test. Some of these returned tubes were examined, and there were indications of longitudinal cracks which, however, might have been, and in fact, looked like, minute die scratches as a result of the cold-drawing operation. A number were cup up and carefully examined under the microscope, but in no instance could any crack or offending non-metallic inclusion be found.

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tinning copper containing high percentages of oxygen. Oxygen-free copper is to be preferred. (*iv*) The viscosity of the tin bath should be maintained as high as possible. Low temperatures and additions of copper are favourable in this respect. (*v*) The object should not be removed from the tin bath so slowly that dewetting can easily occur during the operation.

The Influence of Surface Alloying on the Strength of Soft-Soldered Joints

The experimental work dealt with in this paper by Mr. R. Chadwick was undertaken with the object of improving the strength of soldered structures made from thin copper strip. The suitability, as solders, of a number of low-melting alloys was studied both at normal and at elevated temperatures.

Thin copper strips were joined by soft soldering, using various lead-in alloys and also pure tin and pure lead. A rapid method of joint-making was developed, so that large numbers of joints could be made under reproducible conditions, the influence of variables such as time and temperature of joining, surface preparation, fluxing, etc., being first studied.

It was found that for pure tin and alloys containing tin, brittle copper-tin alloys were formed at the copper surfaces during joining. These copper-tin alloy films were found to increase in thickness by holding joints at elevated temperatures either above or below the melting point of the solder. Fracture on testing occurred near one of the copper surfaces and in the copper-tin alloy film. Three copper-tin alloys were identified, and the part played by each of these distinct and separate layers in joint failure was ascertained.

Using H.C. copper, the joint strength did not decrease below the characteristic strength of the copper-tin alloy layer in which failure occurred. Using a lower grade of copper, failure occurred after prolonged ageing at elevated temperatures by the complete stripping of the solder layer, leaving bright untinned copper, the strength ultimately decreasing to zero. This second type of failure occurred only with copper containing both arsenic and oxygen.

Joints made with pure lead formed no alloy film, and fracture occurred in an irregular manner through the lead, but the formation of a brittle copper-tin alloy film, and also the stripping phenomenon with arsenical copper after prolonged ageing, were observed for a lead-base solder containing only 2% of tin.

The Influence of Alloying Elements on the Crystallisation of Copper. Part I. Small Additions and the Effects of Atomic Structure

In a general way, it is known that the properties of metals and alloys are influenced by the size and shape of the crystals composing them. The effect of crystal size on the mechanical properties of metals and alloys, especially of worked and heat-treated steels, has been discussed in a number of isolated papers, but no systematic work has yet been carried out on the influence of crystal size on the properties of the cast material.

Some control over crystal size may be obtained by modifying the conditions of casting, such as the temperature at which the liquid metal enters the mould, the temperature and material of the mould, and so on, or else by the addition of alloying elements. Although the presence of alloying constituents is known to facilitate the formation of equi-axial crystals in the cast ingot, this is usually explained as being due simply to the alloy having a range of temperature over which it freezes, as compared with a single temperature in the case of a pure metal. Unfortunately, there appears to be no information either on the fundamental factors affecting restriction of crystal growth or even on the relative effects of different alloying additions in this direction. An investigation was therefore initiated to obtain information on these points, and the present paper by Dr. L. Northcott describes the results of an attempt to assess the relative influence of small quantities of added elements in reducing the columnar growth of cast copper, and to determine the fundamental factors on which such influence depends. It was considered advisable, in the first instance, to investigate the crystallisation of copper containing small amounts of different elements, as the properties of such alloys usually lend themselves more easily to generalisations less likely to be complicated by such features as irregularities in freezing range, limited liquid solubility, or the formation of metallic compounds. The effect of large additions and the influence of crystal size on the properties of the alloys will be discussed in later papers.

The influence has been determined of additions of from 0·1 to 2% by weight of alloying elements on the size of columnar crystals of copper cast into moulds specially designed to ensure uni-directional solidification. Different elements produced widely different effects on the crystallisation of the copper. The results are discussed from the points of view of composition gradient and adsorption effects. The temperature gradients in the ingot during and after solidification have been measured. An examination of the valency and atomic structure of the added elements shows a correspondence between these and what has been termed the "crystal growth-restriction factor."

The International Nickel Company of Canada, Ltd.

The report of the International Nickel Company of Canada, Limited, for the year ended December 31, 1937, shows a net profit of $50,299,623·81, after all charges, including provision of $10,350,890·20 for taxes, and $8,761,161·22 for depreciation, depletion, retirement and other purposes. The comparable figure for 1936 was $36,865,526·11, indicating an increase in net profit of approximately 36% over that for the previous record year. After disbursement of $1,933,898·75 for preferred dividends there remained $48,365,725·06, equivalent to $3·31 per share on the 14,584,025 shares of common stock outstanding. This compares with $2.39 per share in 1936.

Sales of nickel, according to Robert C. Stanley, chairman and president, exceeded those of 1936 by 23%, notwithstanding a marked decrease in consumption in the United States during the last quarter. There was an increase in sales of copper over prior years, while sales of the platinum metals, although approaching record volume during the first nine months, decreased sharply in the final months. The price of nickel remained unchanged, except for a downward adjustment in the sterling price at the beginning of the year. The prices realised for copper and platinum declined during the last four months. The earned surplus rose from $59,896,143·55 at the close of 1936 to $70,950,662·36, as of December 31, 1937. Cash increased from $44,871,895·34 to $48,871,395·90 in the same period despite payment of $32,800,880·25 in dividends on the common stock during 1937, as against $18,951,619·70 in the previous year.

Business Notes and News

The Bessemer Gold Medal

THE Council of the Iron and Steel Institute announce that they have awarded the Bessemer Gold Medal for 1938 to Dr. C. H. Desch, F.R.S., Superintendent of the Metallurgical Department of the National Physical Laboratory, Teddington. The presentation will be made at the annual general meeting of the Institute, on May 4, 1938.

Dr. C. H. Desch has long been distinguished as a teacher of metallurgical chemistry. He was lecturer in this subject at the University of Glasgow and, subsequently, Professor of Metallurgy at the Royal Technical College, and later at the University of Sheffield, where he succeeded the late Professor Arnold. His text-book on "Metallography" has been for many years the classical publication on this subject in Great Britain. He is a leading authority on the chemistry of solids, upon which he gave a series of lectures recently at the University of Cornell. In 1932 he was appointed to succeed the late Dr. W. Rosenhain, F.R.S., as Superintendent of the Metallurgical Department at the National Physical Laboratory. Since that time he has been in charge of researches which have for their object the production of metals of the highest degree of purity obtainable, for the purposes of research—in particular the metals of the iron group. Under his leadership, methods have also been worked out for estimating, in a satisfactory manner, the oxygen content of steels. He is a Past-President of the Faraday Society and President-Elect of the Institute of Metals.

Another Giant Turbine for Ford Factory

A CONTRACT has been placed with a well-known British company (The British Thomson-Houston Co., Ltd.) for the installation of a second 30,000 kw. turbo-alternator in the For power house, at Dagenham, and the work of installing its condenser has already begun. This condenser, like that already in use, will be supplied with water pumped from the River Thames at the rate of nearly two million gallons per hour. Each condenser contains 8,600 tubes, 62 miles in total length, and weighs 39 tons.

The Ford power house is already equipped with a 30,000-kw. turbine of similar type, and its output capacity at present is equal to supplying a town twice the size of Northampton.

These turbines, which are among the most modern in this country, are designed to run in such a way that sufficient steam for heating the whole factory is extracted at a pressure of 200 lb. per sq. in.

A New Technical Film

THE showing of technical and educational films in this country is not so general as in France and Germany, where 30,000 projectors are available in schools, colleges and institutions for this purpose.

None the less, British universities and institutions are speedily increasing their facilities for film displays and, as most industrial firms are aware, there is a growing demand for films with industrial and scientific themes. Two-thirds of the equipment installed is suitable only for sub-standard 16 mm. silent films which at the moment are popular because they enable an accompanying lecturer to amplify the film with appropriate remarks according to the needs of any particular audience.

The Bureau of Information on Nickel has just produced a 16-mm. silent film on these lines entitled "Nickel Alloy Structural Steels." It indicates some of the many interesting applications of nickel steels to be met with in the automobile, aircraft, coal mining, marine engineering and several other industries. Special sequences devoted to manufacturing processes and outstanding engineering achievements have been photographed with the close co-operation of 20 or more important firms, and the sequences include a great variety of subjects ranging from coal mining practice to the engine-room of the *Queen Mary*.

The film portrays more vividly than is possible by words the ubiquity of nickel-alloy steels in all the heavy industries. It is primarily for the use of engineering societies which may obtain it free on request from the source mentioned at Thames House, London, S.W. 1.

Paid Holidays for Blast-furnacemen

AN agreement whereby blast-furnacemen will have seven days' holdiday with pay each year has been reached between the National Council of Associated Ironmasters and the National Union of Blast Furnacemen.

Ford Motor Company Ltd. point out that, in accordance with its policy of granting holidays with pay to all employees with a year or more of service, the blast-furnacemen employed at Ford Works, Dagenham, already receive a fortnight's holiday with full pay. This also applies to the men employed in the coke oven section. These are the only blast-furnaces and coke ovens operated in connection with a motor factory in this country.

Machines that Fight Noise

To reduce noise by achieving greater smoothness of running is one of the leading aims of motor engineers and designers. Undoubtedly one method of securing sweeter running is by improving the quality of the component parts of cars themselves, and at one big factory at least—Wolseley Motors Ltd., of Birmingham—new types of machines are constantly being tried and introduced into the shops.

Grinding crown wheels.

One of the latest Wolseley innovations is known as the Fitchberg machine, believed to be the only one of its kind in the country. This machine grinds the face angles and top angles of crown wheels for Wolseley back axles at the rate of tbout 80 to 150 in an hour, according to their size. By grinding the wheels to extreme limits of accuracy, it greatly improves their quality, and hence their efficiency in use.

Although the operations necessary are highly complicated, they take only about half a minute to perform. This modern wonder machine is electrically and hydraulically controlled with a complete system of interlocking controls that hold the finished sizes to limits of plus or minus half a thousandth of an inch.

Some of George Kent's Orders

Messrs. George Kent Ltd., of Luton, have received large orders for small water-meters from South Africa, Australia, New Zealand, South America, Malaya and many other parts of the British Empire.

Many orders for venturi, venturi flume, weir and orifice recorders have been received from the British Isles, and from New South Wales, Trinidad, South Africa, and Queensland, whilst steam meters, steam flow meters, panels and instruments for boilers and turbines account for a substantial amount of business. Included in the latter is an order for complete instrumentation for a 60-ton open-hearth furnace including one RTE/ID producer-gas meter, one RTD/IE air meter, one 6-pt. Multelec temperature recorder, one 2-pt. vacuum recorder, one 12-in. dial pressure-gauge and a CO_2 recorder.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£100	0	0

ANTIMONY.

English		£81	10	0
Chinese		67	0	0
Crude		40	0	0

BRASS.

Solid Drawn Tubes	lb.	0	0	11¼
Brazed Tubes	,,	0	1	1¼
Rods Drawn	,,	0	0	9
Wire	,,	0	0	8¼
*Extruded Brass Bars	,,	0	0	5¼

COPPER.

Standard Cash		£39	17	6
Electrolytic		40	2	6
Best Selected		43	5	0
Tough		42	15	0
Sheets		75	0	0
Wire Bars		44	10	0
Ingot Bars		44	10	0
Solid Drawn Tubes	lb.	0	1	0½
Brazed Tubes	,,	0	1	0½

FERRO ALLOYS.

‡Tungsten Metal ° Powder. nominal	lb.	£0	6	1½
‡Ferro Tungsten ° nominal	,,	0	6	0
Ferro Molybdenum °				
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL 2–4% Carbon, scale 12/- per unit	ton	34	15	0
4–6% Carbon, scale 8/- per unit	,,	24	5	0
6–8% Carbon, scale 7/6 per unit	,,	24	0	0
8–10% Carbon, scale 7/6 per unit	,,	24	0	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon. scale 13/- per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/- per unit	,,	49	0	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
‡Metallic Chromium	,,	0	2	5
§Ferro-Vanadium 25–50%	,,	0	14	0
§Spiegel, 18–20%	ton	11	0	0
Ferro Silicon—				
Basis 10%, scale 3/- per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	,,	12	0	0
45/50% basis 45%, scale 5/- per unit	,,	12	10	0
70/80% basis 75%, scale 7/- per unit	,,	17	0	0
90/95% basis 90%, scale 10/- per unit	,,	30	0	0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	18	15	0
§Ferro - Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	5

FUELS.

Foundry Coke—				
S. Wales	—	2	2	6
Scotland	—	2	1	6
Durham	—	1	19	6
Furnace Coke—				
Scotland	—	2	0	0
S. Wales		1	17	6
Durham	1 12 6 to	1	17	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£68	0	0
*Commercial Ingots		51	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	11
*Cored Bars	,,	0	1	1

MANUFACTURED IRON.

Scotland—				
Crown Bars,		£13	10	0
N.E. Coast—				
Rivets		12	15	0
Best Bars		15	15	0
Common Bars		12	10	0
Lancashire—				
Crown Bars		13	10	0
Hoops		14	2	6
Midlands—				
Crown Bars		13	10	0
Marked Bars		15	15	0
Unmarked Bars		—		
Nut and Bolt Bars		11	15	0
Gas Strip		14	2	6
S. Yorks.—				
Best Bars		15	15	0
Hoops		14	2	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	0	11
*Cored Bars	,,	0	1	1
†Strip	,,	0	0	10¾
†Sheet to 10 W.G.	,,	0	0	11¼
†Wire	,,	0	1	0¾
†Rods	,,	0	1	0¼
†Tubes	,,	0	1	6½
†Castings	,,	0	1	3½

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £32 above English Ingots.

PIG IRON.

Scotland—				
Hæmatite M/Nos.		£6	13	0
Foundry No. 1		6	0	6
,, No. 3		5	18	0
N.E. Coast—				
Hæmatite No. 1		6	13	0
Foundry No. 1		5	11	6
,, No. 3		5	9	0
,, No. 4		5	8	0
Silicon Iron		—		
Forge		5	8	0
Midlands—				
N. Staffs. Forge No. 4		5	8	0
,, Foundry No. 3		5	11	0
Northants—				
Foundry No. 1		5	11	6
Forge No. 4		5	5	6
Foundry No. 3		5	8	6
Derbyshire Forge		5	10	0
,, Foundry No. 1		5	14	0
,, Foundry No. 3		5	11	0
West Coast Hæmatite		7	4	8
East ,, ,,		7	3	6

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.	
Per English ton	Kr.190
Billets, single welded, over 0·45 Carbon.	
Per metric ton	Kr.335-385
Per English ton	£17 11 3/£20 3 9
Wire Rods, over 0·45 Carbon.	
Per metric ton	Kr.385-415
Per English ton	£20 3 9/£21 15 0
Rolled Martin Iron, basis price.	
Per metric ton	Kr.290-310
Per English ton	£15 4 0/£16 5 0
Rolled charcoal iron, finished bars, basis price.	
Per metric ton	Kr.360
Per English ton	£18 17 6
f.o.b. Gothenburg.	

SCRAP METAL.

Copper, Clean		£32	0	0
,, Braziery		29	0	0
,, Wire		—		
Brass		22	10	0
Gun Metal		32	0	0
Zinc		8	0	0
Aluminium Cuttings		71	0	0
Lead		13	10	0
Heavy Steel—				
S. Wales		3	10	0
Scotland		3	6	0
Cleveland		3	7	0
Cast Iron—				
Midlands		3	5	0
S. Wales		3	10	0
Cleveland		4	2	6
Steel Turnings—				
Cleveland		2	12	6
Midlands		2	5	0
Cast Iron Borings—				
Cleveland		—		
Scotland		2	2	6

SPELTER.

G.O.B. Official		—		
Hard		£11	10	0
English		15	2	6
India		13	10	0
Re-melted		12	0	0

STEEL.

Ship, Bridge, and Tank Plates.				
Scotland		£11	10	0
North-East Coast		11	10	0
Midlands		11	10	0
Boiler Plates (Land) Scotland		12	0	0
,, ,, (Marine) ,,		—		
,, ,, (Land), N.E.Coast		12	0	0
,, ,, (Marine) ,,		—		
Angles, Scotland		11	0	6
,, North-East Coast		11	0	6
,, Midlands		11	0	6
Joists		11	6	0
Heavy Rails		10	2	6
Fishplates		14	2	6
Light Rails		10	7	6
Sheffield—				
Siemens Acid Billets		11	15	0
Hard Basic .. £6 17 6 to		10	2	6
Medium Basic, £6 12 6 and		10	0	0
Soft Basic		8	15	0
Hoops		11	15	0
Manchester				
Hoops		11	5	0
Scotland, Sheets 24 B.G.		15	15	0

¶ HIGH-SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	£0	3	6
Finished Bars 18% Tungsten	,,	0	4	6
Extras:				
Round and Squares, ½ in. to ¼ in.	,,	0	0	3
Under ¼ in. to $\frac{1}{8}$ in.	,,	0	1	0
Round and Squares, 3 in.	,,	0	0	4
Flats under 1 in. × ¼ in.	,,	0	0	3
,, ,, ¼ in. × ¼ in.	,,	0	1	0

TIN.

Standard Cash		£185	17	6
English		185	17	6
Australian		—		
Eastern		187	5	0
Tin Plates I.C. 20 × 14 box		1	2	6

ZINC.

English Sheets		£29	0	0
Rods		20	10	0
Battery Plates		—		
Boiler Plates		—		

LEAD.

Soft Foreign		£15	10	0
English		17	10	0

* McKechnie Brothers, Ltd., Mar. 11. † C. Clifford & Son, Ltd., Mar. 11. ‡ Murex Limited, Mar. 11.
Subject to Market fluctuations. Buyers are advised to send inquiries for current prices when about to place order.
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The A B M T M group of machine tool makers covers the whole field of machine-tool building, giving the engineer at home and abroad a unique manufacturing and sales service.

Apart from the main specialities of the Associated firms, customers have the advantages of the pooled research, the accumulated experience and the entire technical resources of the whole group.

The abundant advantages thus provided by group co-operation will be obvious. The after-sales service is of a kind beyond the scope of the single manufacturer.

For further particulars write to:

17, GROSVENOR GARDENS

LONDON—S.W.1

ASSOCD. BRITISH MACHINE TOOL MAKERS LIMTD.
TRADE MARK

FILE THIS IN YOUR CABINET

You will then be able to refer to contents of previous issues easily.

METALLURGIA. Contents. **For MARCH, 1938.**

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T. J. Priestman, Ltd., Birmingham.

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McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Priestman, T. J., Ltd., Birmingham.

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Fordath Engineering Co., Ltd., West Bromwich.
G.W.B. Electric Furnaces, Ltd., Belgrave House, Belgrave St., W.C.1.
I.C.I. Cassel Cyanide.
Kasenit Ltd., Henry St., Bermondsey St., London, S.E. 1.

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William Mills, Limited, Grove Street, Birmingham.
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Northern Aluminium Co., Ltd., London.

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McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Northern Aluminium Co., Ltd., London.

Fluxes.
Foundry Services Ltd., 285, Long Acre, Nechells, Birmingham.
Imperial Chemical Industries Ltd., Dept. C.6, Imperial Chemical House, London, S.W. 1.

Forging Machines
Schiess Detries, A.- G., Düsseldorf.

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General Electric Co., Ltd., Magnet House, Kingsway, W.C. 2.
G.W.B. Electric Furnaces, Ltd., Belgrave House, Belgrave St., London, W.C. 1.
Integra Co., Ltd., The, 183. Broad Street, Birmingham.
Kasenit Ltd., Henry St., Bermondsey St., London, S.E. 1.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham

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Ofag Ofenbau, Düsseldorf, Germany.
Priest Furnaces Ltd., Albert Road, Middlesbrough.

Fused Blocks
Imperial Chemical Industries Ltd. Dept. C.6, Imperial Chemical House, London, S.W. 1.

Gas
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Schloemann, A.-G., Dusseldorf, Germany.

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Calorizing Corporation of Great Britain, Ltd., 32, Farringdon St., London, E.C. 4.

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Printed for the Proprietors, The Kennedy Press, Limited, 21, Albion Street, Gaythorn, Manchester, by Percy Brothers (1937), Limited Hotspur Press, Manchester and London.